STUDIES ON THE ANATOMY AND HISTOLOGY OF OLFACTORY ORGANS OF CERTAIN TELEOSTS

SUMMARY

THESIS PRESENTED FOR THE DEGREE OF

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IN

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AT

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BY

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DEPARTMENT OF ZOOLOGY
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SUMMARY

The anatomy and histology of olfactory organ of five freshwater teleost fishes (C. carpio, H. fossilis, N. notopterus, A. armatus armatus and C. denricus) have been described. The olfactory chamber in all five fishes lies on the dorso-lateral surface of the head. It is situated close to eye orbit in C. carpio, close to snout in H. fossilis, in between eye orbit and snout in C. denricus, extending from eye orbit to snout in N. notopterus and A. armatus armatus. In the latter species olfactory chamber is enormously elongated and barrel shaped.

The olfactory chamber in all the fishes under investigation communicated out side by an incurrent, anterior and an excurrent, posterior nasal openings. The nasal openings in C. carpio and C. denricus lie very close to each other but in N. notopterus and H. fossilis at a considerable distance. The anterior and posterior nasal openings in A. armatus armatus are situated at the two extremities of the elongated snout.

The anterior nasal opening in H. fossilis, C. denricus and A. armatus armatus is in the form of a tube which is anteriorly and forwardly directed. In A. armatus armatus anterior nasal tube is considerably elongated which opens on the either side of fleshy rostral appendage forming a trilobed structure at the termination of upper jaw.

The anterior nasal opening in C. carpio and N.notopterus is nontubular but born on a thickened rim which in former species bears a nasal flap but in latter provided with a nasal tentacle. The nasal flap and tentacle help in deflecting the water to the anterior nasal opening in C. carpio and N.notopterus respectively.

The posterior nasal opening in all the five fishes flush with the general surface of the skin and is valved in H.fossilis and M. armatus armatus. It is nonvalvular in N. notopterus, C. carpio and A. denricus. In latter two species, it is considerably wide and allows a constant contact of the olfactory epithelium with water. The posterior nasal opening in H. fossilis and M. armatus armatus is made up of two lips which in former are known as anterior and posterior lips while in latter as ventral and dorsal lip. The former lip extends over the latter in both the species giving a shape of a valve. The integumental surface of posterior nasal opening in continuously making valvular movements which helps in creating the water current through the olfactory chamber.

The olfactory rosette shows a great variation in shape, size and number of lamellae in all the five fishes. On the basis of categorization proposed by Bateson (1889), Burne (1909) and Teichmann (1954), the leaf or boat shaped rosette of H. fossilis and N. notopterus can be placed under Bateson (1889) rosette type 2; Burne (1909) rosette column II and Teichmann

and Teichmann (1954) rosette group III; oval rosette of C. carpio under Bateson (1889) rosette type 3; Burne (1909) rosette column I and Teichmann (1954) rosette group I; rounded rosette of E. denricus under Bateson (1889) rosette type 3; Burne (1909) rosette column III and Teichmann (1954) group 2. The enormously elongated barrel shaped rosette of A. armatus armatus has not yet been reported correctly and, therefore, cannot be placed in any of the categorization mentioned above.

The olfactory rosette in C. carpio, H. fossilis, E. denricus and N. notopterus bears an antero-posteriorly elongated raphe, dividing it in two equal halves. The lamellae are attached on both the sides of raphe in all these four species. In A. armatus armatus rosette is raphe-less and is made up of two dorsal and ventral halves, fitted on each other by their lateral hinges. Here four rows of lamellae (two in each half) are present which arise from the floor of each half.

The number of lamellae varies from 24-36 in C. carpio, 11-16 in E. denricus, 46-64 in H. fossilis, 58-80 in N. notopterus and 152-240 in A. armatus armatus. The number of lamellae is highest in A. armatus armatus against the highest number 230 reported in Haplomacrous nuentheri (Pfieffer, 1964). The lamellae of C. carpio, H. fossilis, N. notopterus bear linguiform process on their dorsal surface but in the lamellae of A. armatus armatus and E. denricus it is absent.

As regards the relationship of the brain with the olfactory rosette it is found that olfactory bulb is sessile in *A. armatus armatus*, pedunculate in *C. carpio*, *H. fossilis* and *N. notopterus* but it is intermediate in *C. denricus* (intermediate condition is rarely reported in the fishes).

The ecological co-efficient is calculated by the areas of two retinae, two rosettes and by the length of telencephalon and mesencephalon. It is found that *C. carpio* and *N. notopterus* are eye-nose fishes where both the faculties are well developed. *A. armatus armatus* and *H. fossilis* are macrosmatic forms where only olfactory faculty is well developed. *C. denricus* stood microsmatic type of fish where optic faculty is well developed. An attempt has also been made to correlate the eye-nose, macrosmatic and microsmatic characteristics of these fishes with their general habits. Macrosmatic *A. armatus armatus* and *H. fossilis* lead a nocturnal life inhabiting a dark places and mud holes. Microsmatic *C. denricus* leads an active life in day hours, swimming and feeding actively on the surface of water. *N. notopterus* and *C. carpio* being "eye-nose" fishes lead active life both in the day and night hours.

The flow of water through the olfactory chamber is unidirectional in all the five fishes which is created by the antero-posterior beating of cilia. In *H. fossilis* the creation of water current through olfactory chamber is assisted by the compression and expansion of ventro-lateral accessory sac but

in M. armatus armatus continuous valvular movement of posterior nasal opening assists in bringing the water current through the olfactory chamber.

The olfactory passage of M. armatus armatus is longest whereas in C. carpio and E. denricus it is shortest. In H. fossilis and N. notopterus the passage is of moderate size. The vestibule and gallery is well demarcated in H. fossilis and N. notopterus but in M. armatus armatus vestibule takes a shape of lumen. In H. fossilis posterior lamellaeless area contribute in the formation of well defined galley. Corridors are the interlamellar spaces which inter connect the vestibule with gallery. In M. armatus armatus anterior accessory sac is present, which entangled mud and other foreign particles and mud free water is allowed in the lumen of the rosette.

Histological observations reveal that each lamella in all the five species (C. carpio, H. fossilis, N. notopterus, M. armatus armatus and E. denricus) is made up of a central core or submucosa, lined on either sides by the cellular layers of mucosa. The basement membrane stands as partition inbetween the mucosa and submucosa. The mucosa in C. carpio, H. fossilis, M. armatus armatus and E. denricus is mainly constituted of supporting cells, receptor cells, mucous secretory goblet cells and basal cells. N. notopterus possesses all the above mentioned cellular composition except mucous secretory goblet cells.

The olfactory epithelium of lamella in all the five fishes, shows a great variation in the composition of olfactory epithelium and number of microformations are observed in the present investigation.

The olfactory epithelium of the lamellae of C. carpio is provided with number of microformations such as hillock elevations, straight projections, bifurcations, trifurcations and crupts of variable shape and sizes, lying embedded at different depths in the olfactory mucosa. The crupts accommodate large number of primary nurones and open through the surface of lamella by narrow or broad opening, forming well defined "olfactory bud" where olfactory cilia and protruding ends of dendrites receive the sensation from the water current passing through the interlamellar spaces. All the microformation and crupts lead to increase the area of olfactory surface in C. carpio.

A tremendous tendency of the transformation of supporting cells in the mucous secretory goblet cells is noticed in the C. carpio, therefore, whole of the peripheral surface of the lamella is seen occupied by the thecs of goblet cells.

The migration, grouping, fusion and subsequent rupture of large number of the goblet cells are seen scattered in the olfactory epithelium of C. carpio. This activity of goblet cells causes the displacement of basal cells which may flow to any direction leading to microformation. The rupture of the goblet

cells in groups causes the interruption of the olfactory epithelium in the form of crypts. The grouping of the dendrites of rod shaped receptor cells on the general surface of olfactory epithelium also form "olfactory bud" in C. carpio.

On the basis of cellular composition, the lamellae of a rosette in H. fossilis can be divided in initial, middle and hinder groups. The initial and middle lamella show a zonal differentiation inbetween the proximal and distal regions. The former is composed of columnar ciliated supporting cells with rich distribution of spindle shaped receptor cells while latter is lined by the goblet cells intermingled with non-ciliated supporting cells. The hinder lamellae do not show any zonal demarcation and are uniformly lined by the nonciliated cuboidal supporting cells where submucosa is enormously developed. The beaked micro-goblet cells and spindle shaped receptor cells are distributed among the cuboidal supporting cells irrespective of any zonal distinction.

The minor and curved lamellae are seen in the olfactory epithelium of H. fossilis. The bud formation is noticed in the hinder lamellae which after detachment from mother attached on adjacent recipient lamella and adds immediate growth to the latter.

The terminal parts of some lamellae in H. fossilis are seen discharging "cell balls" by the process of gradual

constriction of the underlying region. At the places of curving and attachment with bud, the terminal ends of lamella show a abnormal swelling in the submucosa which may be due to the accumulation of basal cells, blood capillaries and connective tissue etc. required for the fulfilment of these processes (attachment and curving).

In N. notopterus the clear cut zonation of sensory and supporting zones can be observed in all the lamellae in an uniform pattern. The proximal region on either sides of the raphe in each lamella is demarcated as nonciliated, microvillous and sensory zone while remaining distal region is known as ciliated supporting zone. The synaptic contact inbetween the axon of primary nurones and dendrites of spindle shaped receptor cells can be frequently seen in the sensory zone of N. notopterus.

The olfactory epithelium of E. denricus and M. armatus armatus is almost uniform except in latter species where terminal tips of the lamellae are solely occupied by the primary nurones. In E. denricus faint elevations and depression are observed in the general surface of the lamella which are alternately supplied with longer (olfactory cilia) and smaller cilia. In the proximal region of few lamella, morphogenetic activity of cells can be observed which give rise to protuberance like structure bearing goblet cells and aggregation of basal cells in E. denricus.

The olfactory epithelium of *A. armatus armatus* and *E. denricus* is supplied with primary nurones and spindle shaped receptor cells. *H. fossilis* bears only one type of receptor cells which correspond to the spindle shaped receptor cells lying deep in the olfactory epithelium. *C. carpio* possesses primary nurones, spindle shaped and rod shaped receptor cells at variable depths in the olfactory epithelium. *N. notopterus* is provided with spindle shaped receptor cells and primary nurones which make synaptic contact inbetween them. The olfactory vesicle of variable shape and sizes is seen at the terminal end of the dendrites of the receptor cells of *C. carpio*, *E. denricus*, *A. armatus armatus* and *N. notopterus* but in *H. fossilis* dendrite projects into the interlamellar space by a simple olfactory cilia. The olfactory vesicle in *C. carpio*, *E. denricus*, *A. armatus* armatus and *N. notopterus* bears either olfactory cilia or microvilli or both.

The migratory tendency of the goblet cells can be demonstrated in the olfactory epithelium of *C. carpio* and *A. armatus armatus* where goblet cells are produced by mucipe-rous basal cells and undergo a cyclic movement from basal zone to supporting zone where mucous is discharged.

The aggregation of basal cells is reported in the olfactory epithelium of *C. carpio*, *N. notopterus*, *E. denricus*, and *A. armatus armatus* at variable depths of mucosa, giving an

impression of their possible transformation in other cellular constituents of the olfactory epithelium in the process of the repair or replacement of the damaged or worn out parts of the mucosa. In H. fossilis aggregation of basal cell is reported in "cell ball" and "bud" which may probably be supplied to other needy parts of the olfactory epithelium.

The branched pigment cells are observed in the submucosa of N. notopterus, C. carpio, H. fossilis, which are found submerged in the connective tissue fibre. The pigmentation in M. armatus armatus is in the form of thick pigment sheath encircling the whole rosette and giving it a dark black appearance.

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I certify that "Studies on the Anatomy and Histology of Olfactory Organs of Certain Teleosts", is the original work of Vijai Indra Sharma and is suitable for submission for the award of the degree of Doctor of Philosophy in Zoology of the Aligarh Muslim University, Aligarh. This work has been done by the candidate under my supervision.

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INTRODUCTION AND HISTORICAL REVIEW

INTRODUCTION AND HISTORICAL REVIEW

If an organism is to be successful and survive in the complex world in which it lives, the activities of all its organs must be integrated so that the organism will function and will make appropriate responses to its external and internal environment. In the higher animal, integration is accomplished by special receptor or sense organs which detect changes in the environment. Specially for the fishes whose life is entirely confined to the aquatic medium, olfactory sense organs play a decisive role in the location of food, fright reaction to alarm substances and recognition of co-specific individuals. The study of the olfactory organ of fishes is of a great significance because it is one of highly sensitive, sensory organ which is very important to these exclusive aquatic animals. The olfactory organ of fish demonstrate the great variability which can be found with in a specialised organ adopting in different species to diverse environmental and behavioural conditions.

The sense of olfaction is a long range type of reception in which informations are gathered from a distance, similar to that of lateral line system. At the same time a fish may stumble upon a sense of odors as it swims around its habitat. Capability of differentiating the water of different rivers by smell has also been reported in the fishes. Teichmann (1957,

1959) demonstrated that traut could percieve the presence of phenyle ethyle alcohol at a concentration of 0.9 to 10^{-9}m. He further reported that the perception power varies markedly from species to species.

Earlier investigations regarding the anatomy of the olfactory organs of fishes are those of Burne (1909), Allison (1953), Hagelin and Johnels (1955), Kleerekoper and Barkel (1960), Trujillo-Cenoz (1961), Johnson and Brown (1962), Kubiak (1962), Branson (1963), Gooding (1963), Pfeiffer (1963, 64), Bannister (1965), Moulton and Beidler (1967). The generalised review on the anatomy of the olfactory organs of fishes have been published by Kleerekoper (1969), Teichmann (1954) and Hara (1975). The recognised Indian workers who carried out their research work on the anatomy of the olfactory organs of Indian teleost fishes are those of Kapoor and Ojha (1972 a,b, 1973 a,b) and Ojha and Kapoor (1971, 1972, 1973 a,b and 1974). Their two papers are also seen on the histology of the olfactory epithelium of Labeo rohita (1973) and Channa punctatus (1974). But except above authors and to some extent Rahmani and Khan (1980) and Singh (1972) no work on the histology of the olfactory organs of Indian teleost fishes has so far been published. Reviewing the existing literature it is found that the work on the olfactory organ of the European fishes has been carried out to a extent but little work has been done on Indian teleosts. Consequently the present work on the anatomy and histology of the olfactory organ of certain teleost

has been studied broadly to provide a basis for the further applied study on this important organ. The present study of the olfactory organs, therefore, gives a comprehensive account of the structure, shape and size of the olfactory rosette, lamellae, nasal cavity and the accessory sacs (wherever present). The position of rosette in relation to cranial bones and varied structure of the nostrils has also been taken into the consideration. The topographical study of the relationship of brain and olfactory rosette has also been studied from anatomical point of view. The area of both the rosettes were calculated and compared with the areas of both the retinae for making the approximate assessment of the sensitivity of the olfactory and optic surfaces (Teichmann, 1954). Cellular component of olfactory epithelium, receptors, nerve and blood supply has been studied in detail from histological point of view.

The author carried out his research work on the topic "Studies on the anatomy and histology of olfactory organ of certain teleosts" on five fishes of different habit and habitat. The selected fishes are: Cyprinus carpio var Communis (German strain), Linnaeus; Heteropneustes fossilis (Bloch); Notopterus notopterus (Pallas); Mastacembalus armatus armatus, Gunther and Saccus denricus (Hamilton-Buchanan). The habit, habitat, distribution and identifying characters of these fishes are given herein.

Cyprinus carpio var communis (German strain) Linnaeus,

is commonly known as 'mirror carp' and originally native to the region from the Black and Caspian seas to Turkistan. From there it was spread by introduction through out most of the temperate waters of the world.

According Jhingran (1975) C. carpio is an exotic fish but now is commonly cultivated singly as well as along with major Indian carps. He further described that 'murror carp' was brought in 1939 from Ceylon to Nilgiris and stocked Ootacamund lake. It was generally thriving best at high altitudes, but for the first time, on April 18, 1955, it was introduced in the Pucca tank at Nahan (Sirmur district, Himanchal Pradesh). At present this common carp enjoys global distribution occurring in tropical as well as temperate regions acclimatized to variety of habitat and extremes of environment (Alikunhi, 1966).

Present author obtained it from 'Kalai Fish Farm' owned by a local resident for commercial purposes with the assistance of Fisheries Department, Aligarh and financed by State Government. It was situated nearly 25 kms away from Aligarh Muslim University campus on Atreuli Road. In this local farm fishes were stocked in mud tank and fed by the grasses and dairy affluents.

The body of C. carpio var communis (German strain) is moderately deep, slightly compressed and fully covered by the regularly arranged rows of scale. Mouth is directed forward

and protrucible, two pair of barbles are present on upper lip.

C. carpio is an omnivorous feeder and its natural food constitutes small animals and parts of the plants. It feeds varociously by rapidly protruding and retracting the jaws. The fish is very much active in day and actively swimming near the surface of water. Very easily becomes pat to the master and uses to come on banks in shoals.

Heteropneustes fossilis (Bloch)

H. fossilis is distributed in the fresh waters of India, Pakistan, Ceylon, Burma and China. It is commonly known as 'Singhi' and is an elongated catfish with a broad, flat head and transverse mouth. The fish is specially characterised by the accessory airbreathing organs and four pairs of long barbles, two nasals, two maxillaries and four mandibles.

The fish may thrive best in the vary oxygen-poor waters and in soft, sandy and most preferably in muddy bottom soil. It can also be located in some holes or cavities among stones, roots, strong and sparse plants.

It is not markedly piscivorous species and feeds on insects, ostracopods, worms, algal matter, organic debris etc., cannibalism is also reported in this fish. It feeds varociously and lives for years together in captivity. H. fossilis is a nocturnal fish and is also found in mud holes in dry seasons where it may live for days together.

Notopterus notopterus (Pallas)

N. notopterus is distributed in the fresh waters of India, Pakistan, Burma, Siam, Malaya Archipelago and Phillipines. It is commonly known as 'knife fish' or 'feather back' and can easily be identified by a long anal fin which begins just behind the head and extends along the under surface of the body to the tip of tail. The tail fin as such is not evident.

It is a bottom feeder and is found in quite weedy reaches of greater rivers in flood plain and stagnent waters. N. notopterus rests during the day singly or in shoal in the shelter of old stems and thick floating plants. During night they move instantly, close over the bottom, seeking small prey such as insect larvae, worms, small fishes etc.

These fishes are widely distributed in the inland fresh and brackish water streaches of India. They live quite peacefully with other fishes provided they are not considerably smaller.

Mastacembalus armatus armatus Gunther

M. armatus armatus is distributed from India and Ceylon through Thailand to Southern China also in Sumatra. It belongs to the group of 'Spiny eels' of fresh water forms but is not related to true eels because of some anatomical peculiarities, such as markedly elongated sensitive snout supported by a special cartilage. The anterior tubular nasal opening forms a

trilobed appandage at the end of the snout. The posterior nasal opening lies further back near the eye.

It is a nocturnal fish and in day time hides in mud holes with only the tip of snout protruding out from the borrow. M. armatus armatus shows a peculiar borrowing habit in which knocking and forward wriggling motion allow the gradual incersion of the fish body into the mud.

On sun set fish comes out in search of small prey chiefly worms, insect-larvae and small crustacean. They thrive best in weedy waters over a muddy or sandy bottoms.

Esomus denricus (Hamilton Buchanan)

E. denricus is distributed in India, Ceylon, Thailand and Singapore and exceeding upto 150 mm in length but in captivity fishes are curtailed in size as compared to wild forms. They are commonly known as 'flying barb' with elongated, slim, strong and posteriorly compressed body. The mouth is protrucible and upwardly directed with two pairs of barbles; one pair of short and fleshy barble on the snout; another pair are maxillary barble, extending upto the middle of the body. It is a surface feeder and actively swimming on the surface of water. It is active in day hours.

It is an omnivorous fish with most varied food such as dephinia, insect larvae, water lice, fresh water shrimps, copepodes and maggots etc. E. denricus inhabits in ponds, ditches, reservoirs and rivers.

The receptors are main detector of external stimuli throughout the animal Kingdom but in vertebrates they become more specialised and complicated in their function and structure. Stimulatory sensation of the surrounding environment, in the form of first hand information, is collected by these receptors, through the external medium and transmitte. to the central and peripheral nervous systems for the realisation of the sensation. The environmental medium in which animal lives plays a decisive role in transmitting the stimuli upto the receptor concern; such as air for the terrestrial animals and water for the aquatic animals. The receptors can be distinguished broadly as chemical (olfaction and taste) physical (photoreception and thermoreception) mechanical (position and motion etc.).

The fishes are the basic vertebrates and their life is entirely confined to the aquatic medium, specially for these aquatic vertebrates sense of olfaction plays a very important role in constantly informing the changes of abiotic and biotic factors of the surrounding environment. The sense of olfaction is highly specialised with high sensitivity insuring perception of traces, of stimuli and slow adaptation so that giving smell may continue to function as signal for sometime. Because of these specialised properties sense of olfaction plays a decisive role in feeding, defence, spawning, schooling and migratory habit.

No doubt traces of the study of olfactory organ are available in late eighteenth century. But information regarding

sense of olfaction was incomplete. Earlier workers have given a very little attention on the study of the olfactory organ of fishes.

Sophie Pereyaslawzeff (1876) studied the anatomy of the olfactory organs of Solea impar and Lophius piscatorius. This study was coarse and no full paper was available on the said topic.

Blaue (1884) studied the anatomy of the olfactory chamber and rosette in Belone, Exocoetus, Trigla, Esox, Umbra, Cottus, Gobius, Gadus. This paper was important one and was published under the title of the olfactory membrane in fishes and amphibia. The generalised anatomy of olfactory pit and rosette was discussed.

Wiedersheim (1887) published a full interesting account of the stages of degeneration of the olfactory organs of Plectognaths and their change from a simple cavity to a split tentacle which is fully exposed to the water. He selected Tetrodon nigromaculatus, T. immaculatus, T. papua, T. peradalis and Diodon maculatus for this specialised study.

Bateson (1889) was assigned by the Council of Marine Biological Association, London to study the perception of fishes, specially on those which plays a decisive role in recognising the food in aquatic medium. Besides the study of other sense organs he put a stress on the study of the olfactory organs of

fishes. In a very generalised manner and pointed out (i) tubular character of anterior nostril in few fishes that hunt their food by scent (*Motella*, *Cobitis*, *Solea*, *Conger*, *Anguilla*, *Lepadogaster*), (ii) the valvular mechanism of the posterior nostril in certain flat fishes, (iii) the main type of the structure of rosette; elongated in eels, oval in the majority of fishes or circular in *Cottus* and exceptional type in which the leaflets are arranged in parallel series in a single row (*Pleuronectus* and *Hippoglossus*). A generalised account of the arrangement of plates in the olfactory rosette had also been described by Bateson (1889) in the following manner: (i) In skate and dog fishes plates are arranged in a radiating manner on the inside of a hollow capsule, like the septa of orange. (ii) The conger and eel have the plates of the organ arranged in two rows on each side of the central raphe, upon which the two rows are folded longitudinally so as to form the lining of the olfactory tube. (iii) The olfactory organ are provided with the plates which are fitted together in radiating manner forming a convex eminence in the olfactory chamber. The whole organ is either circular as in *Cottus* and *Motella mustela* or elliptical as in mackerels. In all teleostean mentioned in this discussion, the plates are placed at right angle to the long axis of the body and each organ essentially consists of two rows of such plates united in the middle. (iv) In all species of *Pleuronectus* and *Hippoglossus vulgaris* an entirely different arrangement is found. In these fishes only one row of the olfactory plates is

present. The plates thus arranged in a single series lie in a direction parallel to the long axis of the body.

Bateson (1889) on the basis of the olfactory behaviour divided the fishes into two categories; (i) group of fishes which hunt their food with the help of vision and no reaction to the smell of food was observed. Such fishes do not feed at night,(ii) second group of fishes which seek their food by the smell, vision was never used for this purpose. Bateson (1889) concluded that all the fishes hunting, by smell are to some extent nocturnal animals; the group of the fishes studied by him are those of eel (Anguilla anguilla), marine barbot (Gaidropsarus tricirritus and G. mustela), common sole (Solea vulgaris , Lepidopsetta novanii) dog fish (Scyliorhinus canicula), ray (Raia batis) African lung fish (Protopterus annectens) and starlet (Acipenser ruthenus).

Solger (1894) presented the idea of water circulation through the olfactory chamber. He stated that the alternate compression and expansion of the accessory sac syncronously with the respiratory movement cause the water to flow through the olfactory cavity.

Kyle (1899) studied the presence of accessory nasal sac in connection with the olfactory chamber in the species Hippoglossus pleuronectus, Rhombus, Solea, Pleuronectus. He also tried to correlate the presence of accessory sac with the habit of the fish and concluded that accessory sacs are the

characteristics of the semisedintry fishes not migratory ones. He further reported that the accessory sacs are not only the reservlors for water but are also the mucous secretory structures.

For the long time the independent existence of the sense of olfaction in fishes remain doubtful. Nagel (1894) reported that the characteristics of the sense of olfaction is to receive the sensation from the gaseous substances and for the fishes whose life is entirely confined to the aquatic medium such sensation is not possible. Nagel (1894) and others are of the opinion that ins ite of the well developed olfactory organ in fishes, they act as the organ of gastatory sense.

Uexcull (1895) contradicted the erroneous idea of Nagel (1894) by conducting his experiments on the sharks (Mustelus canis). He observed that the shark, whose epithelial lining of the olfactory sac is operated, locate their food with great difficulty as compared to those having olfactory epithelium entacted. The operated shark use to swallow sardines heavily coated with quinin which was soon discarded from the buccal cavity.

Herrick (1908) in his researches of the nervous system of the olfactory and gastatory senses, distinguished categorically these two senses on the basis of the reception of the stimulation. He demarcated the olfactory sense as the distant receptors where the gastatory sense is localised on the oral cavity and can be

perceived only by the touch of the material of gastatory sense.

Burne (1909) described the olfactory organ of teleostean fishes and observed that the olfactory chamber belonging to 32 families and 52 genera differ comparatively little in shape and relatively in size. In nearly every case, olfactory rosette occupies a constant and fixed position with regard to the bones of skull, being lodged in a hollow in ethmoid between the point of articulation with the palatine and lacrymal bones. The nostrils, perhaps, the most variable part, also in that in which variation is correlated least with the natural affinities. The position of the anterior nostril directly above the rosette is almost universal, no doubt in order that the current of water may pass directly upon the olfactory epithelium. The anterior nostril specially in the lower teleost is more or less tubular. The tube is well marked in the eels, Siluroids, Anableps and Ophiocephalus. In certain groups the hinder wall of the tube is elevated to form a valvular flap in other groups or genera (Merluccius, Esox, Salmonidae, Clupeidae) this may be replaced by a singular downward prolongation or curtain that dip into the olfactory cavity above the centre of the rosette.

Variation in the form of posterior nostril also depend little upon the affinity. It is either a simple perforation flush with the general surface of the skin which may show considerable differences in size but is either circular, oval,

eccentric in shape, or it is a slit or pin hole closed by walls. The presence of oval or circular form of nostril is observed in many groups but it cannot be treated as a characteristics for those groups.

The valvular condition of nostril recorded in the fishes which possess accessory sacs for forcibly drawing the water through the olfactory chamber by the pumping mechanism. The accessory sacs can be separated for convenience into three series (i) a single sac directed anteriorly from either above or below the rosette (ii) a single sac directed posteriorly towards the orbit (iii) two sacs (ethmoidal and lacrymal nasal sacs) with very definite relation to the ethmoidal and lacrymal region of the face and also constant in their point of entry into the olfactory chamber above and below the hinder end of the rosette.

In the review of olfactory organs of teleostean fishes Burne (1909) proposed four types of the olfactory rosettes and classified them in columns and types of Bateson (1889); first type of rosette is oval in shape and is very commonly observed in the fishes studied by him (Bateson, 1889, type 3; Burne, 1909, column I); second type of the rosette noticed by Burne (1909) is circular in shape and is found in Cyclopterus, Bovichthys, Cottus, Esox, Orestias. It is provided with lamellae radiating in all directions (Bateson, 1889, type 3; Burne, 1909, column III); third type of rosette is elongated with their lamellae arranged

in parallel series at right angle to it (Bateson, 1889, type 2; Burne, 1909, column II). In most of the eels to a less extent in the Siluroids and soles such rosettes are observed; fourth type of the rosette is with transverse axis to the internarial line and the lamellae are attached to its posterior border in parallel series (Burne, 1909, column IV). Such rosettes are observed in Ophicephalus, Hippoglossus and Pleuronectus.

The degeneration of nose is noticed in Lophius where few lamellae are present in the parallel arrangement to one another. In Percesoces the lamellae are entirely absent. The shape of the lamellae is also subjected to great variation from species to species. Burne (1909) places the lamella of Gadus in its starting series and rosette bearing such lamella is categorised under Burne's (1909) column V. Second type is linguiform bearing lamellae where the suppression of the peripheral part of the lamella leads to the exaggeration of the linguiform process which is a particular characteristic of the Salmonidae and Clupidae (Burne, 1909, column VI). Third type of lamellar modification is with very sharp convex lamellae observed in mugil, perca, pegellus or sphyraena and triangular lamellae of eel should also be included in the same series. Suppression of languiform process causes the lamella to become gently curved or with straight free borders, such are seen in Mormyrus, Clarius, Esox, Ornatias (Burne, 1909, column VII).

Parker (1910, 1911), Sheldon (1911), Copeland (1912)

further contradicted the wrong idea of Nagel (1894) and they by the different experiments on fishes, proved that the sense of olfaction plays a very important role in locating the food material in the aquatic medium.

Sheldon (1911) noted that there was no basic difference in the sense of olfaction of fishes and other vertebrates. On the basis of the experimental data collected by Parker and Sheldon (1913) the conclusion was drawn that the sense of olfaction and taste differ not only with regards to the quantity of stimulating substances but also in their concentrations. Organs of olfaction in fishes perceive very dilute solution while gastatory organ perceives more concentrated mixtures.

Strick (1924) conducted his experiment on trained minnows and very convincingly proved the existence of the sense of smell in the fish. He observed that trained minnows can very easily discriminate between the odorous and taste substance. However, trained fishes were unable to discriminate odorous substances after the removal of forebrain.

The olfactory organs in the fishes are represented by a pair of olfactory pits which in sharks and rays are located on the ventral surface and sturgeons and bony fishes on the dorsal surface of the head. The olfactory pit is lined by olfactory epithelium which is generally raised in the form of serial folds or lamellae. Each nasal pit generally opens outside by two openings, anterior inlet and posterior outlet.

The olfactory organs are diversely developed at one extreme they are well developed such as in elasmobranchs and most of the eels and at the other they are poorly developed such as pike, flying fish, stickle back, pipe fish, angle fish. On the basis of the olfactory ability Frisch (1941) denominated the former group of fishes as macrosmates and the latter as microsmates. This classification is also accepted for the animal of other vertebrate groups. In shark and rays olfactory pit usually lies on the ventral side of the snout. The opening of each pit is divided by the skin flap which are attached medially and laterally into anterior inlet and posteior outlet. In some species posterior outlet directly opens into the mouth. In a Holocephalid Chimaera monstrosa the olfactory chamber is communicated dorsally with the naso-oral groove. The formation of naso-oral groove is due to the extension of two external nostrils along the upper lid towards the mouth cavity. While the mouth is closed, water passes through the external nostril along the naso-oral groove and through the internal nostril into the mouth cavity. It is reported by Holl (1973) that since the olfactory chamber communicates dorsally with the naso-oral groove it is always supplied with the water.

In the teleost fishes a wide variation in the location, size, structure and degree of development of olfactory organ have been reported. Burne (1909), Liermann (1933), Matthes (1934), Teichmann (1954), Holl (1965), Singh (1972), Zeiske

(1973, 1974) have presented a generalised account of the olfactory organ of fishes, although there is no extensive review of the nasal anatomy of all species. However, Laibach (1937), Eaton (1956), Jhonson and Brown (1962), Branson (1963), Pfeiffer (1963, 1964, 1968, 1969), Devitsyna (1972), Kapoor & Ojha (1972, 1973a, 1973b), Ojha and Kapoor (1971, 1972, 1973a, 1973b, 1974) and Rahmani & Khan (1977, 1980) carried out their studies on single species of teleost fishes. Kleerekoper (1969) and Hara (1975) published a review on the anatomy of the olfactory organ of fishes and presented critically the anatomical peculiarities of the olfactory organs of some groups of the fishes on the basis of previous literature available.

According to Hara (1975) the paired olfactory pits are usually situated on the dorsal side of the head. The eels and morays are provided with long olfactory pits extending from tip of the snout to the eye orbits. Such fishes, with elongated olfactory pit, have most acute sense of smell. Contrary to the above findings in Tetradontiformes, the olfactory pits are totally abolished and nasal flaps are exposed to the water. Such fishes are provided with very regressed capacity of sense of smell. Marshall (1967) reported that bathypelagic fishes have sexual dimorphism in the olfactory organisation. The males have large well developed olfactory organs while females with small and regressed ones.

Great variations are reported in the arrangement of the folds of olfactory epithelium which vary from species to species.

It is very commonly observed that rostro-caudally elongated raphe present in most of the fishes which acts as the place of attachment of olfactory folds in the central part of the olfactory rosette. The variation in the number of lamellae in few species was reported by Munder (1957) as 2 in Gasterosteus aculeatus; 9-18 in Esox lucius; 11-19 in Thymellus articus; 14-18 in Salmo gairdneri; 30-32 in Lota lota, 60-90 in Anguilla anguilla. Shibuya (1960) and Pfeiffer (1964) recorded 80 to 90 and 230 lamellae in Channa argus and Haplomacarus guentheri, respectively. Hara et al. (1973) recorded 12 to 14 and 12 to 16 lamellae in Salvelinus fontinalis and Coregonus clupeaformes, respectively. It is critically studied by Kapoor & Ojha (1972a,b, 1973a, b) and Ojha & Kapoor (1971, 1972, 1973, 1974) that lamellar development is always from anterior side to posterior. It is, therefore, concluded that posterior lamella is oldest and largest. No addition of lamella is reported to the lateral ends. Number of lamellae in a fish depend upon the size of the animal.

Teichmann (1954) collected the data regarding the number of lamellae present in a particular fish and concluded that the number increases to some extent with the length of fish. In addition to the formation of new lamellae, each lamella increases in their size. Thus the area of olfactory epithelium of individual fish is considerably increased with the formation of new lamellae and by the growth of those already present.

Teichmann (1954) for the first time reported the presence

of the secondary lamellae in rainbow trout. However, he confuses them as the artifact of preservation. Pfeiffer (1963) observed the same secondary formation in the lamellae of Pacific salmon and rainbow trout and thus the existence of secondary lamellae was established.

Pfeiffer (1963), Bertmar (1972), Hara et al. (1973), Bashor et al. (1974) were of the opinion that the secondary lamellae ultimately increase the area of olfactory epithelium. However, it was observed that secondary lamellae are devoid of receptor cells.

Teichmann (1954) attempted to establish a relation between the area of total olfactory surface and those of two retinae. On this basis he classified the fishes under three following categories (i) species in which eye and nose are well developed (Phoxinus and Gobio); (ii) species in which eye is better developed than nose (Esox and Gasterosteus); (iii) species in which nose is well developed as compared to eye (Anguilla and Lota). However, the distribution of the receptors on the olfactory surface does not have any definite relation, therefore, such relation may hardly be of any authentic value. According to Holl (1965) the sensory epithelium of the olfactory surface may be of three type; (i) continuous except for the dorsal part of the lamellae (Ictalurus, Anguilla, Perca, Salmo); (ii) separated in large area between the lamellae (Esox); (iii) dispersed in small islets (Phoxinus, Cyprinus, Carassius).

Eaton (1936) reported in the Centrachide fishes the epithelial folds radiate in spoke like form from the region approximately under the anterior nares. In these fishes two accessory pouches opening from the posterior part of the primary nasal sacs, act as water pump during the protraction and retraction of the upper jaw. Liermann (1933) and Eaton (1936) termed the accessory sacs as 'ethmoidal' and 'medial' pouches.

Pipping (1926) observed that the olfactory capacity is very much related with the nature of transportation of water circulation through the olfactory chamber. On the basis of this relationship the author divided the fishes in four groups, (i) first group include those fishes in which the flow of water passes through the olfactory sac only at the time of the forward movement of the fish. (ii) In the second group movement of water is caused by the pumping action of accessory sacs, water enters and exit through both the nostrils i.e. unidirectional flow of water is absent. (iii) In the third group water movement is unidirectional created by the pumping action of the accessory sacs synchronized with the respiratory action supplemented by the ciliary movement of the olfactory epithelium. (iv) In the fourth group of the fishes water circulation is carried out through the olfactory chamber along with the respiratory movement, supplemented by the ciliary movement of olfactory epithelium. Passage of water current is unidirectional. He further specified that fishes belonging to fourth group have highly developed sense

of olfaction which play significant role in the recognition of food. In the fishes of first and second groups olfaction is weakly developed and does not contribute in the location of fooed in the aquatic medium.

According to Døving et al. (1977) and Døving & Thommesen (1977) the water circulation through olfactory chamber is technically denominated as; Isosmates and Cyclosmates types. In the former group ciliation of olfactory epithelium is responsible for the water circulation through the olfactory chamber whereas in latter group compression and expansion of the accessory sac, in relation to skull bone, bring about the transportation of water through the olfactory epithelium.

The denomination of Døving et al. (1977) in relation to water transportation through the olfactory chamber is further corrected by Derivot & Godet (1979). They very correctly clarified the Isosmates nomineclature of Døving et al. (1977) in the form of Heterocyclosmates and Autocyclosmates. In the former group fishes are dependent on respiratory movement for the circulation of water through the olfactory chamber, whereas in the latter group ciliary action is solely responsible for creating the water current through the olfactory chamber.

Rahmani (1979) in addition to Døving et al. (1977) further elaborated the classification of fishes with regard to the circulation of water through the olfactory chamber and he

put forward another denomination as amphisosmates besides cyclosmates and isosmates. Here water transportation is brought about by the ciliary movement as well as the pumping activity of sacs. The remarkable observation is the presence of window in some lamellae of Colisa fasciatus which facilitate easy water circulation through the olfactory rosette.

Our knowledge pertaining to the histology of the olfactory organ is very meagre. However, some important references in this regard are those of Hopkins (1926), Kolmer (1927), Allison (1953), Trujillo-Cenoz (1961), Branson (1963), Gemne & Doving (1969), Kleerekoper (1969). Our existing knowledge reveals that the plan of olfactory epithelium of the fishes is not very much different as compared to those of other vertebrates. Kleerekoper (1969) described all the cell types and their fibre connection in the olfactory epithelium. Schultze (1856) recognised following types of cell in the olfactory epithelium of vertebrates: receptor cells, supporting cells and basal cells. The presence of sensory and supporting cells in the sensory epithelium of fish, as in other vertebrates, was also observed by Grimm (1873). Dogel (1886) distinguished three forms of sensory olfactory cells, filamentous, rod shaped and cone shaped. In some species of Anguilla and Myxocephalus, large flask shaped mucous cells are observed which are interspersed among the supporting cells. The presence of mucous cells in the olfactory epithelium of other vertebrates show variation in minor detail within a particular

organ. They are filled with secretory substance which is seen extruded out in the interlamellar spaces. Popova (1966) also reported the presence of mucous cells among the supporting cells. In addition to usual cell types, new cellular elements such as secondary neurone or spindle shape cells and primary neurones or rounded cells have been identified by Kapoor & Ojha (1972) in Channa punctatus and Ojha & Kapoor (1973) in Labeo rohita.

Devitsyna (1972) compared two marine species; sea cod (Gadus morrhua) and Novaga (Eliginus novaga) with a fresh water member of the family Gadidae Burbot (Lota lota) on the basis of the histological structure of the olfactory epithelium and bulb. He characterised quantitative distribution of receptor cells along the surface of folds, is irregular in all three species and this is reflected in their concentration in some parts and their thinning out in others. However, the general pattern of the quantitative distribution of the sensory element over the olfactory fold is characterised for each species.

Bertmar (1972) described the olfactory organ of trout on the basis of ecological adaptation. He found that a species from a certain ecological niche has olfactory organ which tend to adapt in a particular environment. He further stressed on the cell population of the olfactory epithelium and defined blastema cells are basal cells which divide into goblet cells, primary receptors and primary supporting cells. The mention of

fibroblast cells has also been done by Bertmar (1972).

Zeisko et al. (1975) studied the development of olfactory organ of oviperous and viviparous cyprinodonts, where they emphasise the sequence of the formation of the nasal opening. According to them the difference is thought to be related to ontogenetic characteristics. Reinke (1936) as quoted by Zeiske et al., (1975) observed that the anterior nare develop from the opening which appears first in both for oviperous and viviperous cyprinidonts. The posterior nare appears latter at another position. This is contrary to many other teleosts (Salmonids and Cyprinids) in which both nares arise from single opening (Gawrilenko, 1910; Reinke, 1936; Teichmann, 1954).

Recent researches dealing with the epithelia of olfactory organs of fishes based on electron microscopy, reveals that four cell types are present in olfactory epithelia of Neoceratodus forsteri i.e. olfactory receptor cells, supporting cells, non sensory ciliated cells and basal cells. Goblet cells may also be present but their shape, size and secretory habit differs variably from species to species. The essential feature of the olfactory receptor cell of Neoceratodus are the presence of microvilli and cilia (Theisen, 1972).

Thornhill (1972) reported the structure of accessory olfactory organ of Lampetra fluviatilis which consist of clustre of inter connected vesicles in tenous connection with the exterior

medium via the cavity of olfactory organ. The wall of the vesicle is composed of two type of cells which are designated as light and dark cells, primary sense cells and supporting cells(Hagelin & Johnels, 1955 and Thornhill, 1972). The primary sense cells which are responsible for the sensation of smell, are provided with peripheral nuclei with their axon directly passing to brain. They differ from olfactory sense cells in the size and number of cilia. It is, therefore, concluded that accessory sense organ of Lampetera is capable of responding to a "special kind" of chemical stimulus. Contrary to the finding of others, Thornhill (1972) suggested that the accessory olfactory organ is morphologically similar to the olfactory epithelium.

Zeiske et al. (1976) studied the epithelium of the olfactory organ of two Cyprinodontoidae species by transmission and scanning microscopy. The relatively flat floor of the organ is covered by sensory and non sensory epithelia. Non sensory epithelium separates the distinct area of sensory epithelium. Difference between the olfactory organs of Xenophorus helerd and Aplocheilus linectus was found to be related to the topography and quantitative distribution of epithelia. The nonsensory stratified squamous epithelium contains numerous goblet cells and surface cells with micro-ridges. The sensory epithelium bears basal supporting and two types of sensory cells i.e. ciliated and microvilous receptor cells.

Recently Yamamoto & Ueda (1977, 1978a, b, c, d, e, f) described the orders Salmoniformes, Clupeiformes, Cypriniformes, Gasterosteiformes, Channiformes, Synbranchiformes, Anguilliformes, Myctophiformes and adopted scanning microscopy process in describing ultra microscopic structures of the olfactory epithelium of the representatives of the above orders. Their main stress was on the different types of ciliation and intercellular contents of the cells of the olfactory epithelium. They described following types of the cells on the basis of their surface specialisation; cells bearing many long cilia on wide and flat surface (type I ciliated cells); those bearing several short cilia which project radially from the round cell apex (type II ciliated cells); those bearing no cilia but a tuft of numerous microvilli (microvillus cells); those bearing neither cilia nor microvilli but protruding as a simple rod from surface (rod cells). Their internal structures are reported to have similar internal microorganels.

On the basis of surface specialization in the olfactory epithelium, Yamamoto & Ueda (1978e) reported that fish with dense cilia arising from type one ciliated cells are believed to have predominently developed olfactory sensitivity such as eels (Schulte, 1972; Yamamoto & Ueda, 1978c), salmons (Bertmar, 1972; Yamamoto & Ueda, 1977) and cod (Lowe & MacLeod, 1975). Contrary to it fishes are having less developed olfactory sensitivity where epithelium lacks type one ciliated cells and cilia are dispersed into small islets such as Atheriniformes (Zeiske et al.,

1976) stickle backs (Bannister, 1965; Yamamoto & Ueda, 1978d).

MATERIAL AND METHODS

Large number of C. carpio of different sizes were obtained from Kalai Fish Farm. C. denricus and H. fossilis were collected from ditches and ponds (Chautal) near the university campus and also from the local fish market Aligarh. N. notopterus were procured from Kalindri river and also from the canal of Thermal Power Station Harduaganj (Aligarh). M. armatus armatus were procured from Budhi Ganga, Ganjdundwara (Etah).

The fishes under investigation were also collected in living condition and were kept in Aquaria for experimental use.

For the study of cranial components related to lacrymal and ethmoidal regions, dried skulls were prepared by removing the scales and skin of the head and then treated with 4% KOH for 2-3 days depending upon the thickness of the tissue. Subsequently muscles were removed with the help of forceps and brushes. The cleaning and bleaching were done by using benzene and hydrogen peroxide. The skulls thus obtained were kept for drying for a day. The observations are made under stereoscopic binocular microscope. Diagrams were drawn with the help of Prism Camera Lucida. Alizarine transparencies of few specimens were prepared by Hollister's technique (1932) to study the

cranial architectural pattern in relation to olfactory chamber.

The olfactory and retinal area were calculated by the Teichmann (1954) method. Prior to the separation of the olfactory lamella, the rosettes were kept in 70% alcohol, which cause stiffness in the lamellae. This allows easy detachment of the lamellae without any damage from raphe and the floor of olfactory chamber. First of all the rosette is cut into two halves through the raphe by sharp blade and then lamellae are gradually separated one by one from anterior side. In A. armatus armatus where raphe is absent, the lamellae are separated from one row of ventral half after detaching the ventral and dorsal halves from each other.

Lamellae were mounted temporarily in glycerine and their diagrams were sketched at a known magnification. Their actual areas were measured by the planimeter. The total area of one half is multiplied by two and thus the value of area of one rosette is calculated. In A. armatus armatus, area calculated from one row of lamellae is multiplied by four for drawing the area of all the lamellae of one rosette. Same is doubled for getting the value of areas of both the rosettes of the fish. For anatomical studies, the fishes of different sizes were fixed in 10% formalin and Bouin's fluid. Heads were dissected from dorsal side under steriescopic binocular microscope for the study of olfactory organs and their relationship with the brain.

The area of eye is measured by planimeter as well as by applying πr^2 formula where 'r' is the radius.

Ecological coefficient by area methods were calculated by the following formula:

$$= \frac{\text{Total area of olfactory lamellae (both the rosette) x 100}}{\text{Total retinal area (both the eyes)}}$$

Similarly ecological coefficient calculated by brain lobe methods can be drawn by the following formula:

$$= \frac{\text{Length of telencephalon x 100}}{\text{Length of mesencephalon}}$$

For histological studies the olfactory rosette and accessory sac (wherever present) were taken out from the narcotized specimens and were fixed in Bouin's fluid for 6-24 hours depending upon the tissues. Transverse and horizontal sections were cut at 6-8 µm in thickness and stained with Mallory's aniline blue collagen stain and Delafield's haemotoxylin and then counter stained with eosin.

To study the water circulation through the olfactory chamber alizarine red solution was injected by hypodermic syringe from both anterior and posterior nasal openings to study the ingress and egress of the water. It was observed that the red solution was seen coming out from posterior nasal opening establishing unidirectional flow of water (from anterior

nasal opening to posterior). Similar results were also obtained by injecting carmine and chalk particles when it was repeated on preserved specimens in which the jaws were mechanically opened and closed.

OBSERVATIONS

Fig. 1. Lateral view of head of C. carpio.

ANT. NAS. OP.	-	Anterior nasal opening.
NAS. FLAP	-	Nasal flap.
POST. NAS. OP.	-	Posterior nasal opening.
RIM	-	Rim.

Fig. 2. Dissection of the head of C. carpio from lateral side to show rosette insitu.

CEN. CH.	-	Central channel
ETH. H.	-	Ethmoidal half
LAC. H.	-	Lacrymal half
LAM. LESS AREA	-	Lamellae-less area
LING.	-	Linguiform process
PER. CH.	-	Peripheral channel
RPH.	-	Raphe
W. OLF. CHAM.	-	Wall of olfactory chamber.


POST. NAS. OP.
NAS. FLAP
ANT. NAS. OP.
RIM

Fig. 1

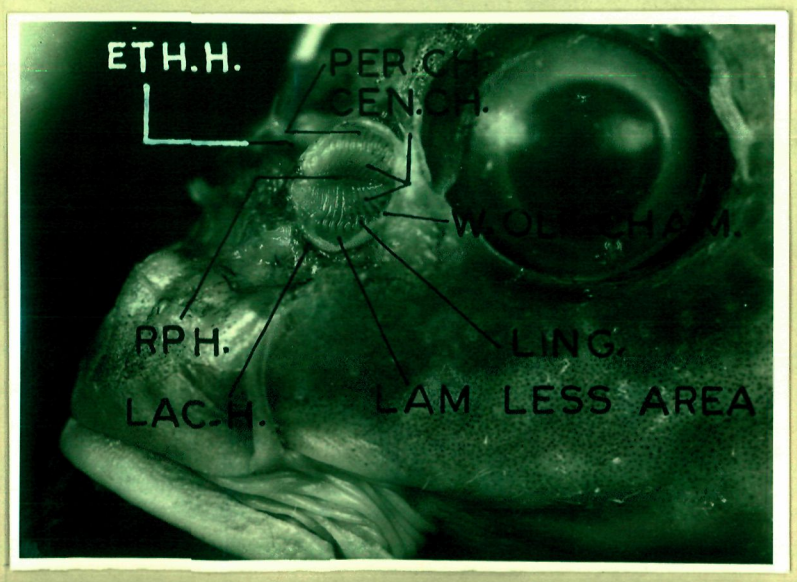
ETH.H.
PER.CH.
CEN.CH.
RPH.
LING.
LAC.H.
LAM LESS AREA

Fig. 2

POST.	-	Posterior
POST. NAS. OP.	-	Posterior nasal opening
RE.	-	Rosette
REM. FLAP	-	Remaining flap
RIM	-	Rim
RPH.	-	Raphe
VEN. EX. FLAP	-	Ventral extension of flap
W. OLF. CHAM.	-	Wall of olfactory chamber.

Fig. 3A. Diagram of the lateral view of the head of C. carpio.

Fig. 3B. Diagram of the olfactory chamber to show nasal flap and posterior nasal opening.

Fig. 3C. Diagram after removing the nasal flap to show the position of anterior nasal opening and rim in C. carpio.

Fig. 3D. Diagramatic sketch of the rosette of C. carpio.

Fig. 3E. A set of 1-18 lamellae from one half of the rosette of C. carpio.

ANT.	-	Anterior
ANT. NAS. OP.	-	Anterior nasal opening
CEN. CH.	-	Central channel
ETH. H.	-	Ethmoidal half
EY.	-	Eye
IN. LAM. SP.	-	Interlamellar space
LAC. H.	-	Lacrymal half.
LAM.	-	Lamella
LAM. LESS AREA	-	Lamellae-less area
LING.	-	Linguiform process
NAS. FLAP	-	Nasal flap
OLF. CHAM.	-	Olfactory chamber
PER. CH.	-	Peripheral channel

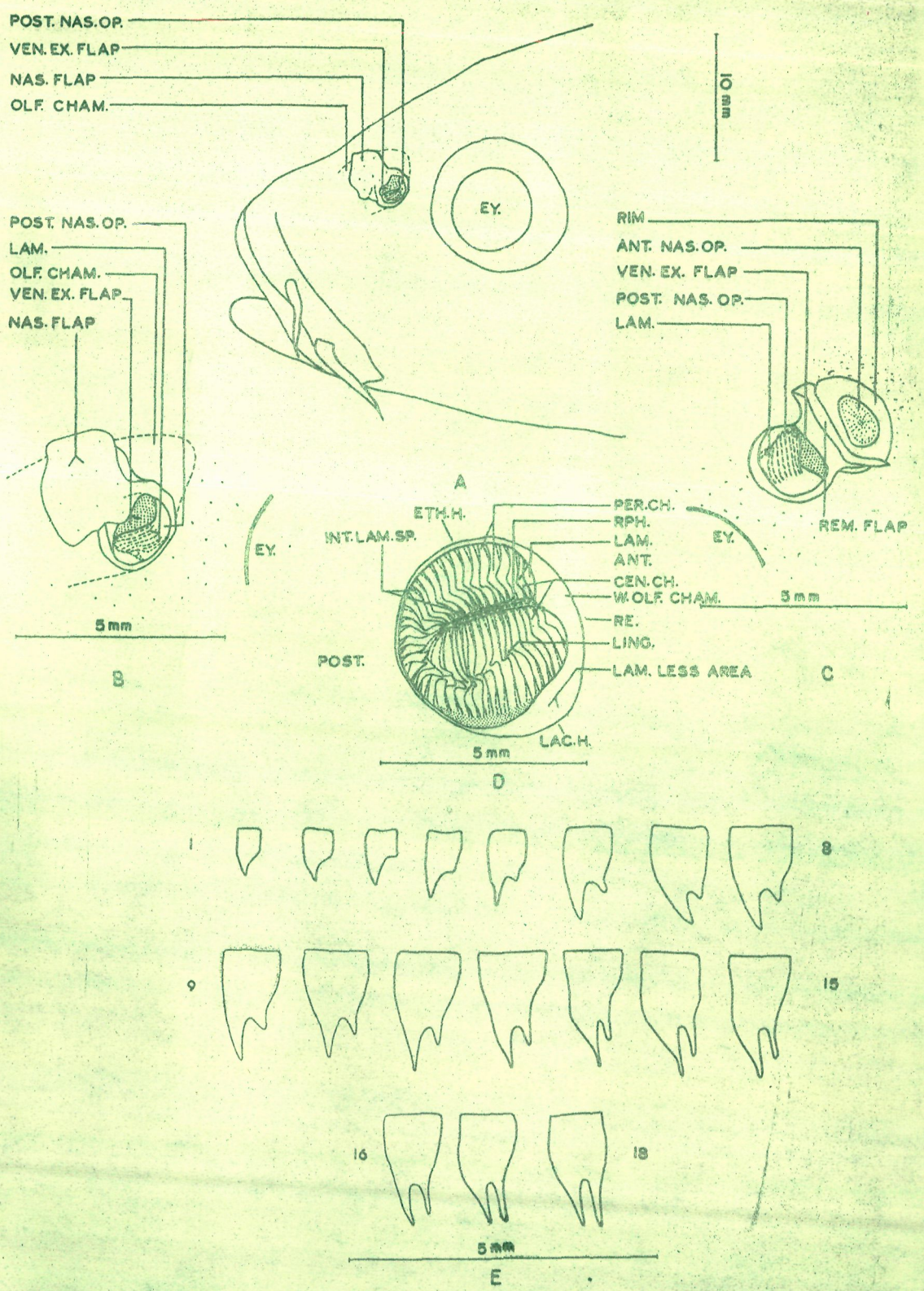
POST. NAS. OP.
VEN. EX. FLAP
NAS. FLAP
OLF. CHAM.
EY.
10 mm
POST. NAS. OP.
LAM.
OLF. CHAM.
VEN. EX. FLAP
NAS. FLAP
EY.
5 mm
B
A
ETH. H.
INT. LAM. SP.
PER. CH.
RPH.
LAM. ANT.
CEN. CH.
W. OLF. CHAM.
RE.
LING.
LAM. LESS AREA
POST.
LAC. H.
5 mm
D
RIM
ANT. NAS. OP.
VEN. EX. FLAP
POST. NAS. OP.
LAM.
REM. FLAP
EY.
5 mm
C
1
8
9
15
16
18
5 mm
E

FIG. 3.

Fig. 4A. Diagram of the lateral view of the skull of C. carpio (Posterior region is not drawn). 2,3,4,5 circum orbitals.

Fig. 4B. Ethmoidal region of the skull after removing lacrymal, ethmoid, nasal and prefrontalbbones to show the floor of olfactory chamber.of C. carpio.

DEN.	-	Dentary
DSPH.	-	Dermasphenoid
ENT.	-	Entopterygoid
ETH.	-	Ethmoid
FRON.	-	Frontal
HYO.	-	Hyomandibular
IOPR.	-	Interoperculum
LAC.	-	Lacrymal
LETH.	-	Lateral ethmoid
MAX.	-	Maxilla
MPT.	-	Metapterygoid
NAS.	-	Nasal
OLF. FOR.	-	Olfactory foramen
OPR.	-	Operculum
ORB. SPH.	-	Orbitosphenoid
PAL.	-	Palatine
PAR.	-	Parietal
PAS.	-	Parasphenoid
PRE. FRON.	-	Prefrontal
PRE. MAX.	-	Premaxilla
PRE. OPR.	-	Preoperculum
PTR.	-	Pterygoid
Q.	-	Quadrate
ROST.	-	Rostral
SOPR.	-	Suboperculum
SUP. ORB.	-	Supraorbital
SYM.	-	Symplectic

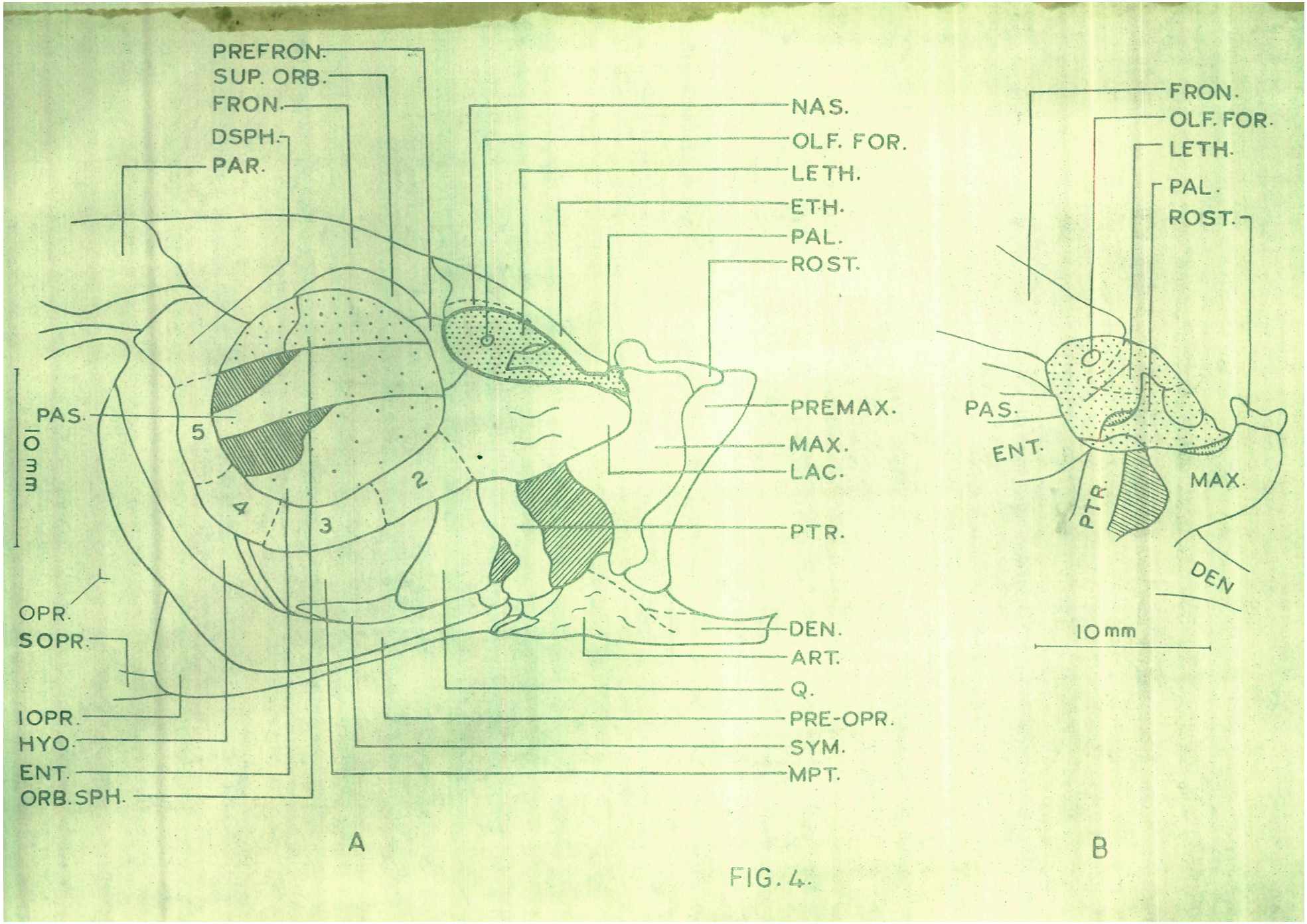
PREFRON.
SUP. ORB.
FRON.
DSPH.
PAR.
NAS.
OLF. FOR.
LETH.
ETH.
PAL.
ROST.
PREMAX.
MAX.
LAC.
PTR.
DEN.
ART.
Q.
PRE-OPR.
SYM.
MPT.
PAS.
5
4
3
2
OPR.
SOPR.
IOPR.
HYO.
ENT.
ORB. SPH.
A
FRON.
OLF. FOR.
LETH.
PAL.
ROST.
PAS.
ENT.
PTR.
MAX.
DEN
10 mm
B

FIG. 4.

Fig. 5. Diagram of the dissection of the head of C. carpio from dorsal side to show the relationship of brain with rosette.

CE.	-	Cerebellum
EY.	-	Eye
OLF. BL.	-	Olfactory bulb
OLF. LO.	-	Olfactory lobe
OLF. TR.	-	Olfactory tract
OP. LO.	-	Optic lobe
RE.	-	Rosette.

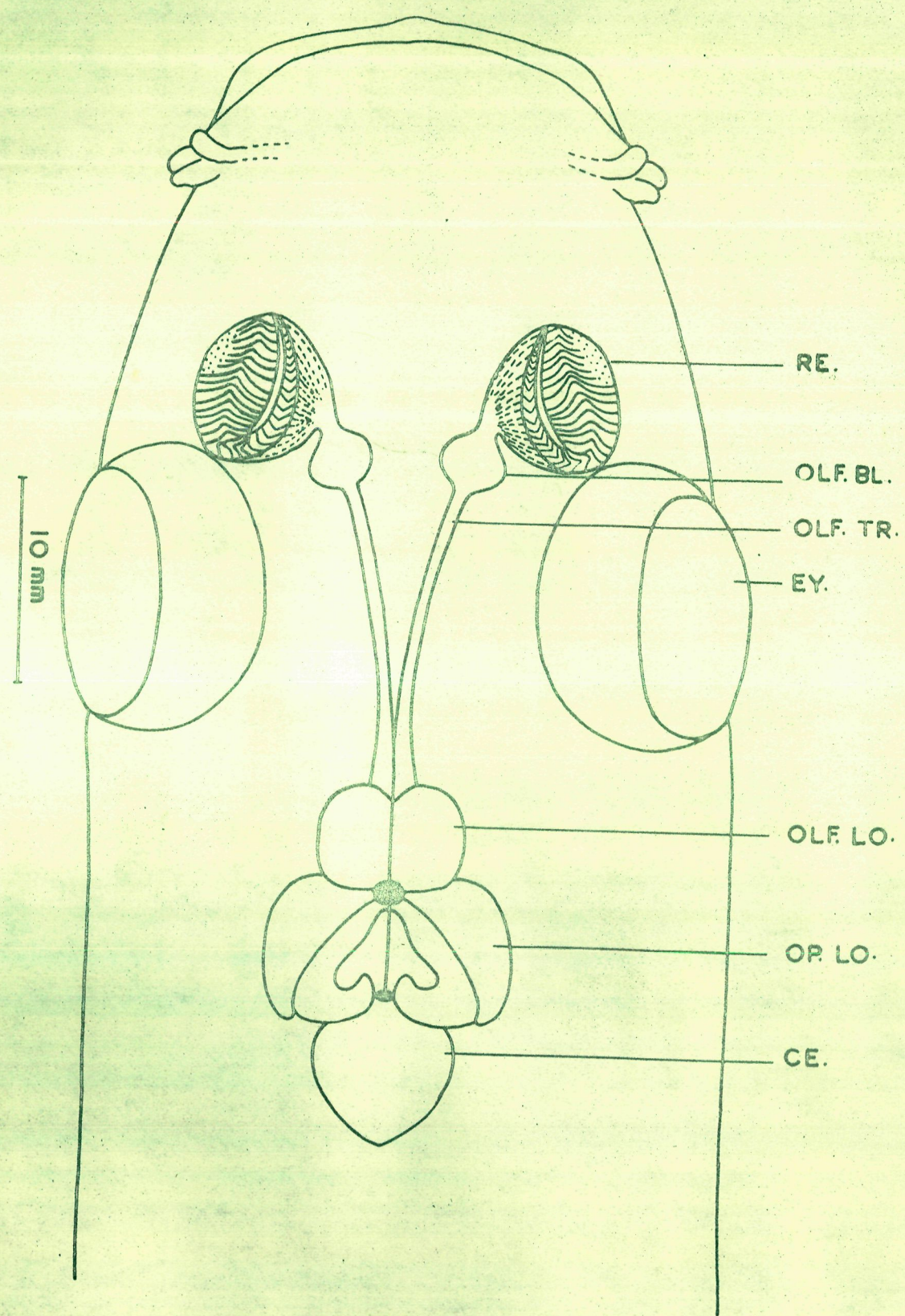

FIG. 5.

ANATOMICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *CYPRINUS CARPIO* LINNAEUS

C. carpio bears a pair of olfactory chambers, lying on the dorso-lateral surface of the head and are more close to the eye-orbit than the snout (Figs. 1, 3A). The olfactory chambers are oval in shape and set surrounded by integumental formation which forms an upwardly and forwardly erected nasal flap (NAS. FLAP, Figs. 1, 3A,3B). It is dipped into the olfactory cavity by its ventral extension (VENT. EX. FLAP), dividing it transversely in the anterior and posterior chambers (Figs. 3A, 3B, 3C). The olfactory chamber is communicated outside by a pair of nasal opening which lies close to each other (Figs. 1, 3C). The nasal flap (NAS. FLAP) acts as partition inbetween them (apertures). The anterior nasal opening (ANT. NAS. OP.) is placed upward from the surface on a distinctly elevated rim (RIM) while the posterior (POST. NAS. OP.) is flush with the surface of the head (Figs. 1, 3C). The former is oval in shape and covers only a small portion of the anterior most part of the olfactory chamber while latter is spherical and large, covering most of the part of the olfactory chamber. The nasal openings allow most of the part of the olfactory chamber exposed to water except that covered by the integumental borders of nasal flap. The rosette can be seen easily through the posterior nasal opening (Figs. 3A, 3B, 3C).

In the fish of 160 mm total length the olfactory chamber is 2.925 mm and is placed at a distance of 9 mm from the snout and 3 mm from eye orbit. The length of the anterior nasal opening is 0.935 mm and the height of the nasal flap is 1.755 mm from the surface of the olfactory chamber. The diameter of posterior nasal opening is 1.755 mm.

The olfactory rosette (ROS.) is oval shaped and occupies the entire olfactory chamber (Fig. 3D). It has a ventral convex and dorsal concave surface with large number of closely set lamellae (LAM., Figs. 2, 3D). A leaf shaped thick raphe (RPH.) divides the olfactory rosette in ethmoidal and lacrymal halves (ETH. H. AND LAC. H.) and extends antero-posteriorly of the rosette (Figs. 2, 3D). In the extreme periphery of the lacrymal half, the olfactory epithelium remains lamellae-less (Lam. LESS AREA), forming a pocket like structure which probably be understood as rudimentary accessory sac (Figs. 2, 3D). This may help in retaining water during the course of its transportation from the olfactory chamber. Each half of the rosette is further divided into peripheral and central channels (PER. CH. AND CEN. CH.) due to presence of linguiform process of all the lamellae in an antero-posteriorly progressing manner. The linguiform processes (LING.) form a curtain like separation in between the channels of each half of the rosette (Figs. 2, 3D). The raphe is richly supplied with chromatophores but in other regions of rosette they are scattered rarely.

The lamellae (LAM., Fig. 3E) are leaf shaped structures lying attached on either sides of the raphe (Figs. 3D, 9, 34). They are possessing ventral convex and dorsal flat surface. The former is attached with the wall of olfactory chamber (W. OLF. CHAM., Figs. 2, 9) where as latter is free and maintain interlamellar spaces (INT. LAM. SP.) among them (lamellae). The proximal end of each lamella is broad and attached with the raphe while the distal end is narrow and attached with olfactory chamber (W. OLF. CHAM., Fig. 3D, 9). The linguiform process is present in the middle of each lamella and are arranged in an antero-posterior ascending series. In few posterior lamellae its (LING.) growth exceeds beyond the distal end of the lamella (Fig. 3E, Nos. 16-18). The chromatophores are present on the linguiform process (1-18 lamellae of one half, Fig. 3E).

The floor of the olfactory chamber is composed of palato-lateral ethmoidal complex. The palatine (PAL.) is broad and triangular bone constituting the anterior part of the olfactory chamber. Its anterior arm is attached to maxilla (MAX.) and posterior two arms extends upto the middle part of the chamber. The greater part of the olfactory chamber is scooped on the surface of the lateral ethmoid (LETH.) in the form of a concavity which is supported postero-ventrally and postero-dorsally by orbito-sphenoid (ORB. SPH.) and entero-pterygoid (ENT.) bones respectively. The dorsal boundary is

covered by the expanded wings of median ethmoid (ETH.) and small nasal bone (NAS.). The nasal bone also forms the dorsal boundary of the two nasal openings. The posterior and ventral boundaries are formed by the frontals and lacrymals (FRON.AND LAC. Figs. 4A, 4B) respectively.

The medial part of the lateral ethmoid bears a large foramen (OLF. FOR.) for the passage of the olfactory nerve fibres arising from the mesial surface of the olfactory chamber and reaches up to the olfactory bulb. The olfactory bulb lies at the junction of orbito-sphenoid and lateral-ethmoid. Each olfactory tract extends through the ventral surface of the orbito-sphenoid bone (Fig. 4A, 4B).

The brain and its cranial connections are exposed after dissecting the fish from dorsal side and removing the frontal and parietals. The olfactory bulbs (OLF. BL.) are conspicuous and bulbous structures, abut against the ventral convex surface of the olfactory rosette (Ros.). It receives the olfactory nerve fibres from the rosette and joins the hemisphere of forebrain by a thick olfactory tract (OLF. TR.). The olfactory lobes are considerably developed but are smaller than the optic lobes (OP. LO.). The cerebellum (CE.) is also considerably developed (Fig. 5).

Ecological co-efficient:

It is calculated by two methods: first by taking the

length as parameter of mesencephalon and telencephalon; second by measuring the areas of two retinae and both the rosettes. By comparing the former and latter parameters, the effectiveness of the olfactory and optic faculties can be assessed approximately from the anatomical point of view.

Five fishes of different sizes ranging from 113 mm to 210 mm are selected for calculating the ecological co-efficient. It is observed that the length of the brain and the number of lamellae increase successively with the size of the fish. The size of the mesencephalon ranges from 2.29 mm to 4.09 mm in length and that of telencephalon from 1.58 mm to 2.92 mm (Table 1).

The areas of two retinae and both the rosettes are measured by the usual methods. It is observed that former ranges from 114.36 mm^2 to 226.08 mm^2 and that of latter from 265.50 mm^2 to 650.24 mm^2 (Table 1). Though the areas of the both rosettes are found to be higher than the retinae but the value of latter is of considerable significance and may not be ignored. The optic centre in brain also shows significant development as compared to other lobes. Considering the above values, it shows that C. carpio bears both olfactory and optic faculties better developed and, therefore, it can be identified as "Eye-nose" fish. In the natural habitat the fish uses both the faculties with equal capability. This can increase the

Table I : Xyrinus carpio (Eye-nose fish)

S. No.	Length	No. of lamellae in rosette		Total length of the Brain	Length of Diencephalon	Length of Telencephalon	Ecological coefficient (Through lobes of Brain) Length of Telencephalon X 100 / Length of Diencephalon	Retinal area of both eyes	Olfactory area of both rosette	Ecological coefficient (Through area) Olfactory area X 900 / Retinal area
		Right	Left							
1.	113 mm	23	24	5.70 mm	2.2 mm	1.58 mm	60.(0	114.36 mm^2	265.50 mm^2	232.16
2.	145 mm	30	30	8.1[illegible] mm	3.27 mm	1.[illegible]8 mm	60.55	127.16 mm^2	280.24 mm^2	220.38
3.	165 mm	32	32	9.77 mm	3.74 mm	2.57 mm	68.71	156.00 mm^2	585.62 mm^2	245.61
4.	195 mm	34	35	10.53 mm	3.86 mm	2.57 mm	66.58	226.08 mm^2	601.44 mm^2	266.02
5.	240 mm	36	36	11.21 mm	4.0[illegible] mm	2.[illegible]2 mm	71.3[illegible]	226.08 mm^2	650.24 mm^2	287.61

general efficiency of the fish and, therefore, C. carpio is considered as most active exotic carp of fresh waters.

The route of water circulation through the olfactory chamber of C. carpio:

The posterior nasal opening is a wide aperture covering most of the area of the olfactory chamber and allowing a exposure of the posterior part of the olfactory rosette to the external medium (Figs. 3B, 3C). Therefore, in C. carpio the olfactory epithelium remains in a constant touch with the water (similar to the gills).

In addition to it forward movement of the fish, synchronously with the unindirectional beating of the cilia (Cl., Figs. 10,11,14, 16,17,18,19) of the olfactory epithelium causes the entry of water current through anterior nasal opening to the central part of the outer concave surface of rosette, where from it is directed to the central and peripheral channels, leading to its ultimate expulsion from the posterior nasal opening. The forwardly directed nasal flap (NAS. FLAP, Figs. 1, 3A) deflects the water current to the anterior nasal opening. During the course of circulation, water passes through the interlamellar spaces and lamellae are bathed properly.

The fish in motionless condition enjoys a constant contact of the olfactory lamellae with water (similar to gills)

through the posterior nasal opening but during forward movement, the current of water enters through the anterior nasal opening and is virtually expelled out from the posterior.

The olfactory epithelium of G. cardio is intensively mucous secretory (Figs. 10,11,12,13,14,15) and it is observed that foreign materials are traped (MU.FGN.) from the water current by the mucous at certain places in the interlamellar spaces (Fig. 24). This may be a device for removing the unwanted foreign material from the water circulating over the olfactory rosette through the outgoing water current. This device can be compared with mucous secretion of the nasal epithelium of mammals which makes the air dust-free before its intake in the alveoli.

Fig. 6. Transverse section of one half of the rosette of *C. garnia* passing through anterior lamellae. The peripheral surface of lamella is uniform showing minimum activity of goblet cells and basal cells. Magnification X 100.

BM.	Basement membrane
CI. SC.	Ciliated supporting cell
CON. TI.	Connective tissue
DE. LAM.	Distal end of lamella
GR. MIG.	Grouping of microgoblet cell
INT. LAM. SP.	Interlamellar space
MG.	Mega- or marginal goblet cell
MU.	Mucous
MU. BC.	Muciperous basal cell
PR. LAM.	Proximal end of lamella
RPH.	Raphe
SMSA.	Submucosa.

Fig. 7. Transverse section of one half of the rosette of *C. garnia* passing through middle, longest lamellae showing migration, grouping, fusion and subsequent rupture of the goblet cells which results the formation of crupts. Magnification X 100.

CR.	Crupt
DE. LAM.	Distal end of lamella
FU. MIG.	Fusion of microgoblet cell
GR. MIG.	Grouping of microgoblet cell
MG.	Mega- or marginal goblet cell
MSA.	Mucosa.
PR. LAM.	Proximal end of lamella
SMSA.	Submucosa.

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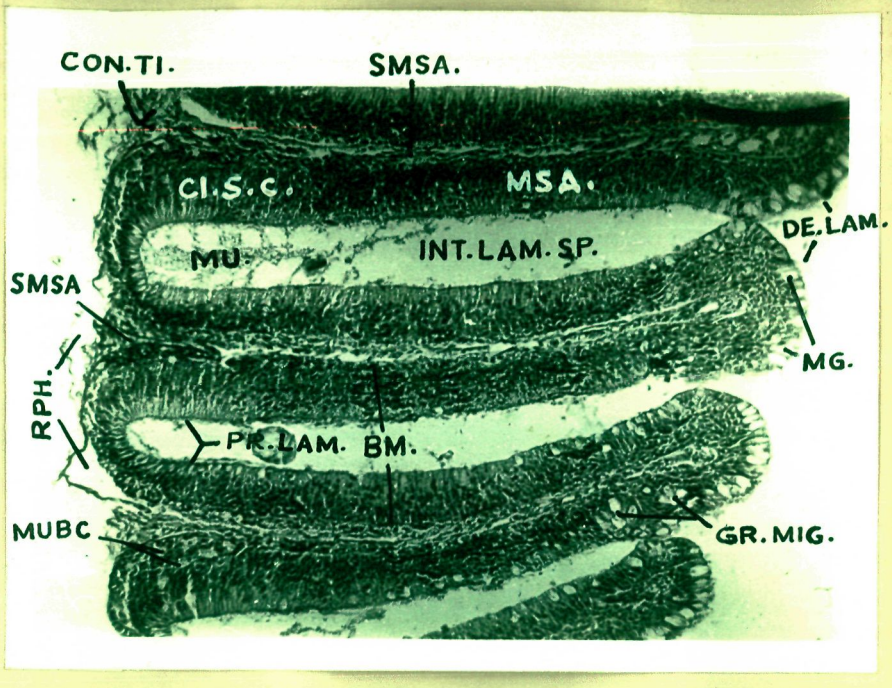

Fig. 6

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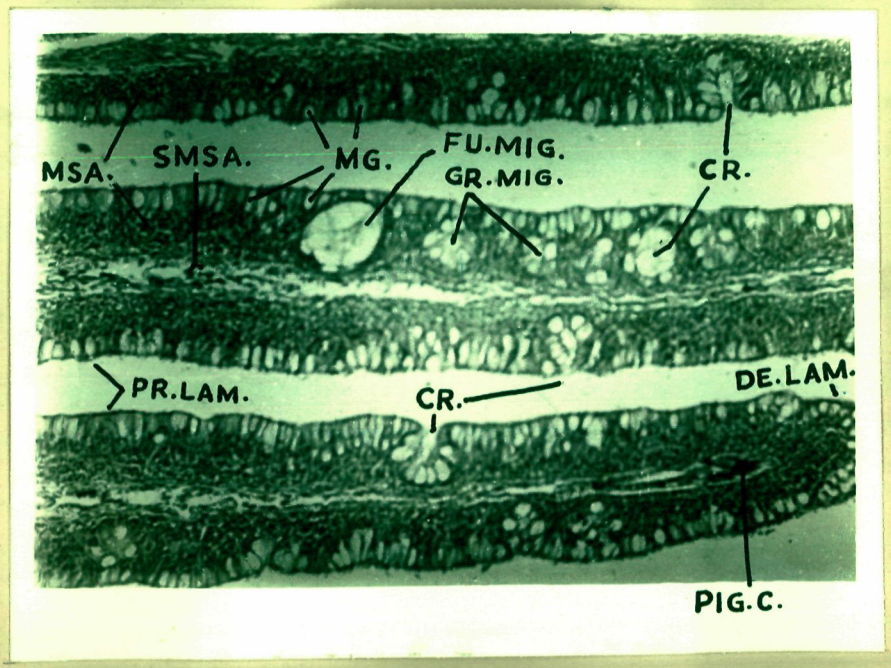

Fig. 7

7

Fig. 8. Transverse section of one half of the rosette of C. carpio passing through posterior most lamellae. Crupts and'olfactory bud' are visible. Magnification X 100.

CR.	Crupt
CI. SC.	Ciliated supporting cell
DE. LAM.	Distal end of lamella
GR. MIG.	Grouping of micro- or migratory goblet cell
INT. LAM. SP.	Interlamellar space
MG.	Mega- or marginal goblet cell
MIG.	Micro- or migratory goblet cell.
MSA.	Mucosa
OLF. BUD	'Olfacoty bud'
RPH.	Raphe
SMSA.	Submucosa

Fig. 9. Horizontal section of rosette of C. carpio showing both the halves and attachment of lamellae on either side of raphe. Magnification X 50.

DE. LAM.	Distal end of lamella
INT. LAM. SP.	Interlamellar space
LAM.	Lamella
PR. LAM.	Proximal end of lamella
RPH.	Raphe
W. OLF. CHAM.	Wall of olfactory chamber.

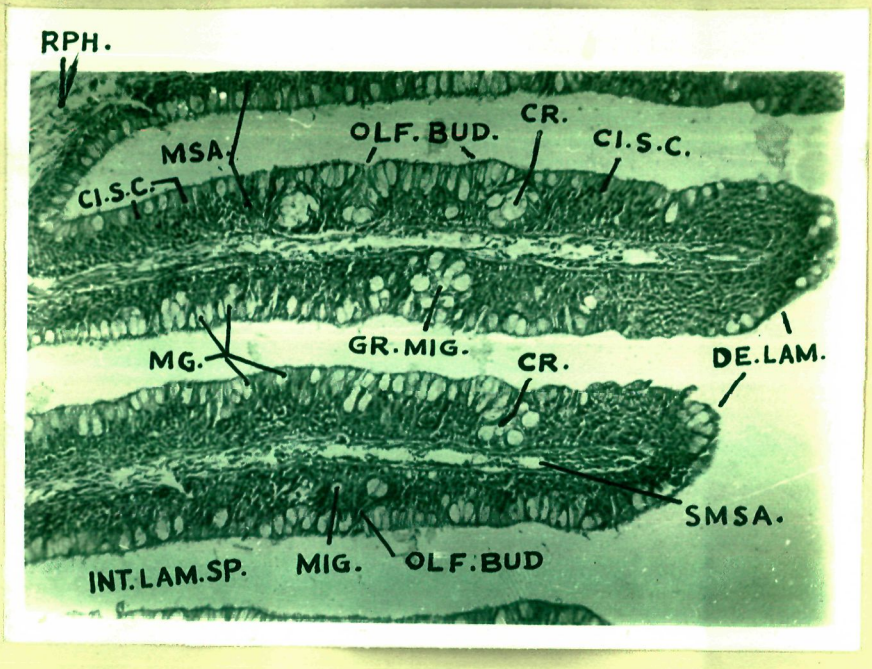
RPH.
MSA.
OLF. BUD.
CR.
CI.S.C.
CI.S.C.
MG.
GR. MIG.
CR.
DE.LAM.
SMSA.
INT.LAM.SP.
MIG.
OLF.BUD

Fig. 8


PR.LAM.
DE.LAM.
LAM.
INT.LAM.SP.
RPH.
W.OLF.CHAM.

Fig. 9

HISTOLOGICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *CYPRINUS CARPIO* LINNAEUS

The olfactory rosette (RE.) of *C. carpio* is oval shaped and is thrown out in number of ventro-dorsally projected folds (LAM.) or lamellae (Figs. 2, 3D, 5, 9). They are attached on either sides of the raphe (RPH.) which is a median thickening of the olfactory floor dividing it into two equal halves (Figs. 2, 3D, 5, 34). All the lamellae are free on the dorsal surface and maintain interlamellar spaces (INT. LAM.SP.) inbetween them (Figs. 3D, 5, 6, 8, 9, 34). Each lamella is made up of a central core or submucosa (SMSA.), lining on its both sides by the cellular component of mucosa (MSA., Figs. 6, 7, 8, 12, 13). The mucosa is composed of pseudo-stratified columnar and ciliated epithelium which is abundantly supplied with the mucous secretory goblet cells (MUC. MIG., Figs. 6, 7, 8, 10, 11, 12, 13, 14, 15). The basement membrane (BM.) stands as partition inbetween the submucosa and mucosa. The peripheral surface of the lamellae is provided with number of micro-formation which are due to the flow of basal cells and bursting of goblet cells at different levels of the olfactory epithelium. They may be in the form of hillock elevations (HIL. EL.), straight projections (STR. PJ.), bifurcations and trifurcations (Figs. 12, 13, 14, 24, 25, 28, 31). The grouping of the goblet cells (GR. MIG.) and their fusion (FU. MIG.) causes the interruption of the olfactory epithelium (INTR. OLF. EPI.,

Fig. 31) leading to the formation of depressions (DPR., Figs., 11, 15, 25), flask, funnel, tubular and rounded vacuole like structures (Figs. 26, 27, 29, 30, 31, 32). The goblet cells burst on the surface in groups (GR. MG.), forming crupts-like (CR.) structures on the periphery of lamellae through which receptors are projecting their olfactory cilia to the inter-lamellar space. The crupts or the openings of goblet cells with their sensory cilia, projecting out to the inter-lamellar space, gives an impression of "olfactory bud", embedded deep in the olfactory epithelium (Figs. 27, 29, 30, 31). The division of the central core or submucosa is seen only in bifurcations and trifurcations (Figs. 12, 13, 14) but in other micro-formation it does not send its offshoots. The formation of secondary lamellae is not observed in C. carpio and micro-formation leads to increase the sensory surface of the olfactory lamella. Only the anterior most lamellae have their proximal and middle lamellar surface uniform (Figs. 6, 10, 11) but others are richly supplied with crupts and microformations (Figs. 7, 8, 12, 13, 14, 15). The "cell ball" (C. BALL, Fig. 13) formation is also observed which are arranged against the distal tip of anterior lamella.

The cellular contents of the olfactory epithelium of C. carpio can be identified as: supporting or sustentacular cells, receptor cells, goblet cells and basal cells. The connective tissue of submucosa and raphe is richly supplied

with branched fibroblasts, histocytes and basal cells.

Supporting or sustentacular cells:

The supporting cells (SC.) of C. carpio are subjected to a process of continuous transformation into mucous secretory goblet cells, therefore, whole of the peripheral surface of the lamella is lined by goblet cells with few intervening supporting cells (Figs. 11, 14, 15, 19, 20, 21, 24).

The nonciliated supporting cells (NCI.SC.) are present in proximal and intervening region of lamellae adjacent to raphe. These cells have elongated cell body with oval nucleus which bear one or two nucleolus. The chromatin material is dust like and uniformly distributed in karyoplasm. The outer or distal limb is elongated, extending upto, the peripheral surface of the lamella (Figs. 16, 17, 18). The ciliated supporting cells (CI. SC.) have long cilia projected into the inter-lamellar spaces showing their unidirectional movement. The distal or outer limb of the ciliated supporting cell (DE. CI. SC.) contains homogenous cytoplasm in the distal regions of lamella (Figs. 10, 16, 17, 18). The proximal limb is inconspicuous and difficult to trace among the other cellular contents lying beneath these cells. The ciliated supporting cells are also present in crupts or opening of goblet cells among the primary neurones (Figs. 29, 30, 31).

The ciliated supporting cells in the middle and distal regions of lamella are comparatively broad and columnar in shape with a slightly convex distal end which project cilia in the interlamellar spaces. They bear rounded or oval nuclei with a nucleolus and faintly visible chromatin material. The nuclei of these cells are larger than the receptor cells and take darker strain as compared to primary supporting cells. The outer or distal limbs of secondary supporting cells (SE. CI. SC.) are thick and filled with ribrillar cytoplasm (Fig. 22). The ciliation is thick and prominent, projecting into the interlamellar space. The ciliated supporting cells may undergo a process of transformation into the goblet cell and transitional stages of these cells (T. SC.) can easily be seen in the olfactory epithelium of C. carpio (Figs. 14, 19, 20, 26, 27). Some ciliated cells are also seen discharging the mucous into the interlamellar space at certain places (Fig. 10).

The receptor cells:

The receptor cells are supplied through out the olfactory epithelium of C. carpio irrespective of their restriction in any particular region of the lamellae. But, however, they are concentrated in crupts and in middle region of all the lamellae. They can be classified into three types: primary neurones (PN.); spindle shaped receptors (SR.) and rod shaped receptors (RR.).

The primary neurones (PN.) are confined in the crupts (Figs. 14, 27, 29, 30, 31) and in proximal region of lamella (Figs. 16, 17, 19) among the nonciliated supporting cells. They bear a rounded nucleus (NU. PN.) which send a fibriller dendrite (DN. PN.) to the peripheral surface. The dendrite is darkly staining. These receptor cells are situated close to the basement membrane as they usually lie in the interruptions caused by the bursting of goblet cells in the form of crupts. The terminal end of primary neurones either bear cilia (CCI., Fig. 19, 21, 22) or protrude as such (DN. PN) in the lumen of crupts which are communicated with interlamellar spaces by their openings (Figs. 27, 29, 30, 31). In this manner olfactory cilia or protruding end of dendrite remain in contact with the water current passing through the interlamellar spaces of the lamella. The independent identity of axone of these receptors are not very commonly traced out due to their insignificant length but, however, at the places of thick olfactory epithelium their clear demarcation can be seen (Fig. 22).

The spindle shaped receptor (SR.) bears elongated and oval nucleus (NU. SR.) with long dendrite (DN. SR.). The axonal end (AX. SR.) is also considerably long and can be easily traced out in thick regions of lolfactory epithelium. Their occurrence is comparatively rare in the olfactory epithelium of C. carpio but, however, they can be observed

Fig. 10. Vertical section of lamella of C. carpio passing through proximal region. The peripheral surface of lamella is uniform and mucous is coming out from supporting cell. Muciperous basal cells are pooled in this region. Magnification X 400.

BC. Z.	Basal zone
CI. SC.	Ciliated supporting cell
CON. TI.	Connective tissue
INT. LAM. SP.	Interlamellar space
MG.	Mega- or marginal goblet cell
MU.	Mucous
MU. BC.	Muciperous basal cell
SC. Z.	Supporting zone
SMSA.	Submucosa.

Fig. 11. Vertical section of lamella of C. carpio passing through middle region. Rod shaped receptor cell, mega- or marginal goblet cells and pigment cells are distributed. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
CON. FIB.	Connective tissue fibre bundle
DPR.	Depression
FB. C.	Fibroblast cell
FOL.	Folium olfactorium
MG.	Mega- or marginal goblet cell
PIG. C.	Pigment cell
RR.	Rod shaped receptor cell
T. SC.	Transitionary supporting cell

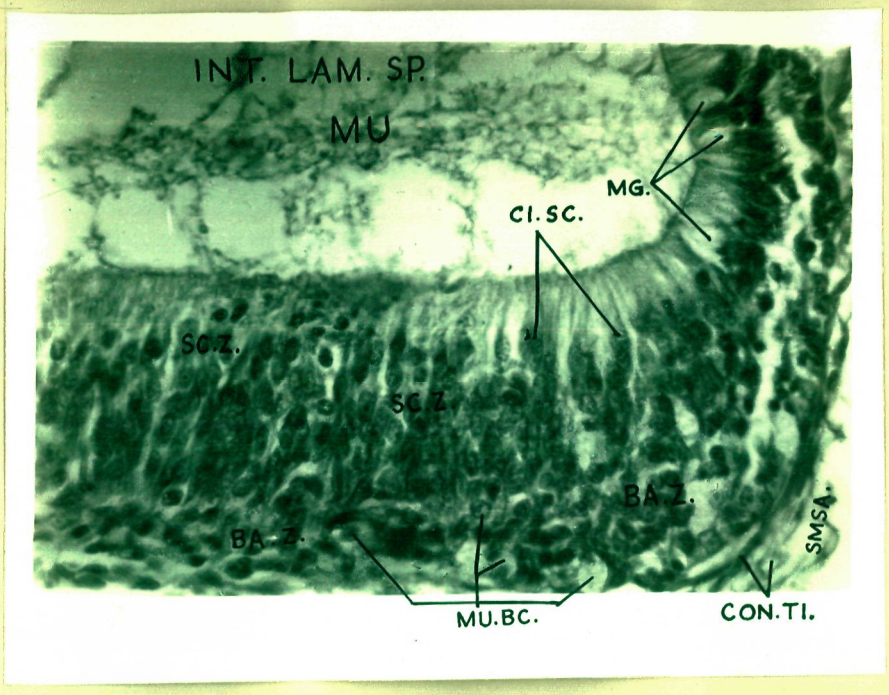

Fig. 10

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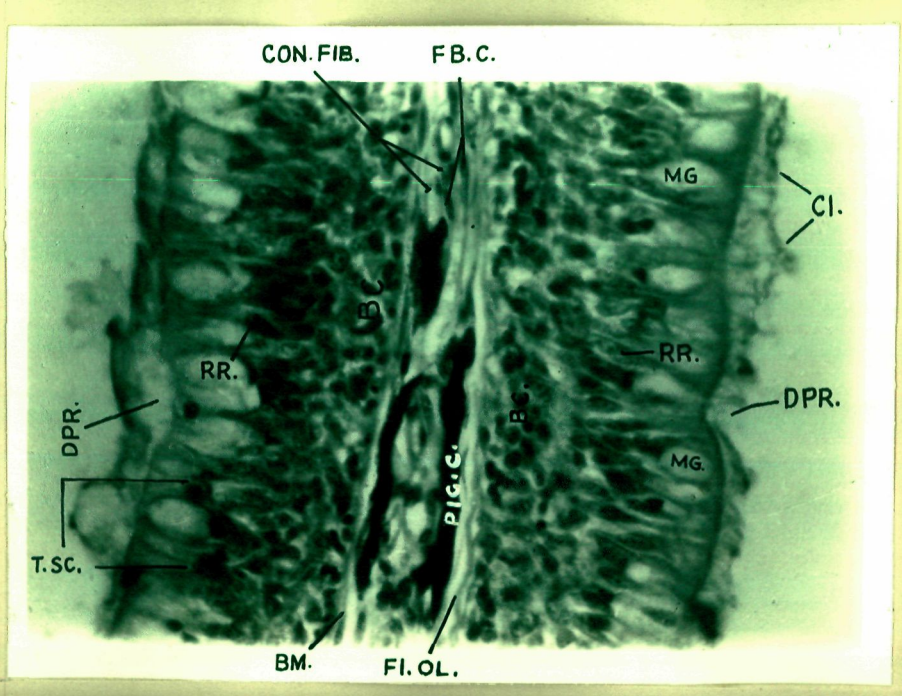

Fig. 11

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Fig. 12. Vertical section through the trified lamella of C. carnio showing the offshoot of submucosa in each outgrowth. Crupts and pigment cells are visible. Magnification X 100.

CI.	Cilia
CR.	Crupt
GR. RR.	Grouping of rod shaped receptor cell
MIG.	Micro- or migratory goblet cell
MG.	Mega- or marginal goblet cell
MSA.	Mucosa
PIG. C.	Pigment cell
SMSA.	Submucosa
TRI. LAM.	Trification of lamella

Fig. 13. Vertical section through bifid lamella of C. carnio showing the offshoots of submucosa in each arm. Magnification X 100.

BC.	Basal cell
BI. LAM.	Bifid lamella
C. BALL	Cell ball
MG.	Mega- or marginal goblet cell
MSA.	Mucosa
SMSA	Submucosa.

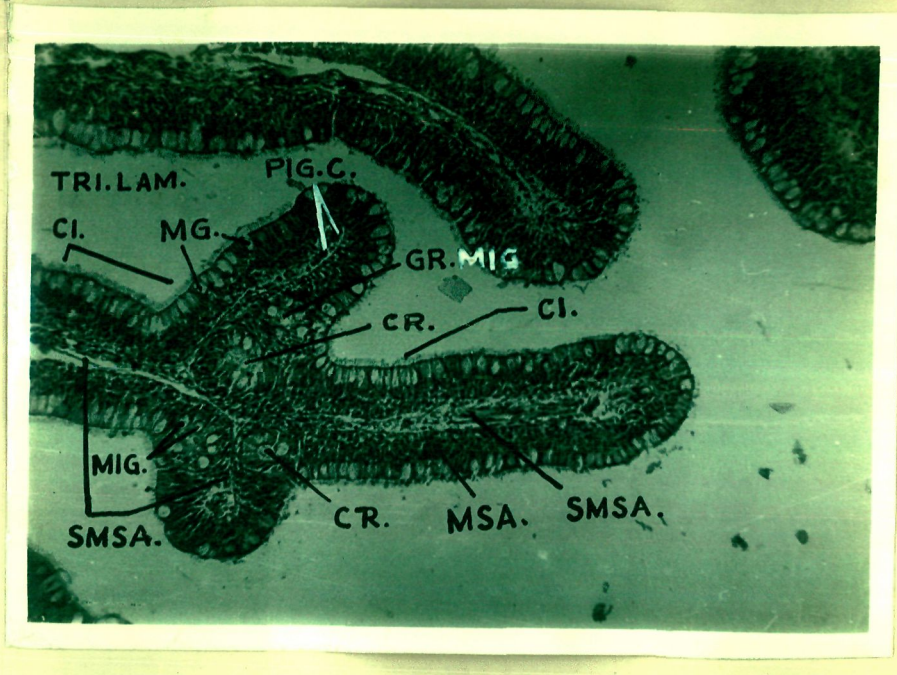

Fig. 12

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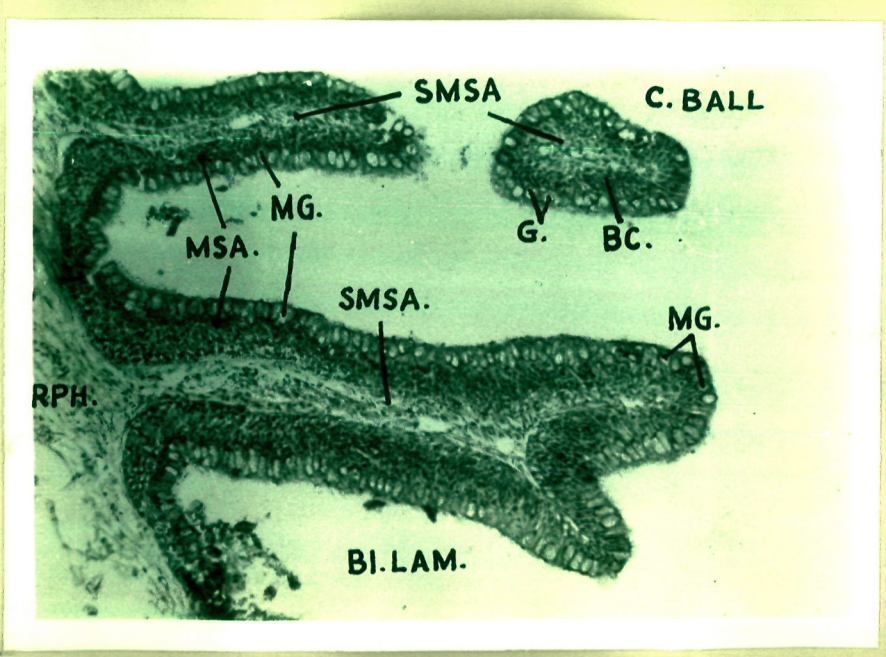

Fig. 13

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among the ciliated supporting cells in thick olfactory epithelium (Figs. 15, 17, 19, 20, 21, 22, 30). They are not present among the marginal goblet cells or in the crupts or in the opening of the goblet cells (crupts)

The rod shaped receptor cells (RR.) are commonly observed in the middle and distal regions of the olfactory epithelium of a lamella. Their dendrites (DN. RR.) are thick and rod shaped extending either inbetween the theca of two marginal goblet cells or traversing singly or in groups through the empty theca of a goblet cell (Figs. 15, 20, 21, 27, 30, 31). The dendrite terminates distally in the form of expanded tip which bears minute cilia projecting in inter-lamellar space (Figs. 11, 14, 15, 20, 21, 27, 31). The rod shaped receptor bears darkly staining narrow and elongated nucleus (NV. RR.). The axon (AX., Fig. 20) is elongated, extending upto basal zone (BC. Z.) where they join to form folium olfactorium.

The olfactory vesicles are observed in the terminal ends of the dendrites of rod and spindle shaped receptor cells in *G. carnia* (Figs. 15, 19, 20, 21). The spindle shaped receptor cells bear rounded vesicle (OV., Fig. 19) while the terminal end of the dendrites of rod shaped receptor cells end terminally in the form of expanded tip forming olfactory vesicle of variable shapes (OV., Figs. 15, 20, 21). They are projected in the interlamellar spaces either by olfactory cilia

or microvilli or both (Figs. 15, 19, 20, 21).

The presence of primary neurone in crupts and the projection of their cilia or protruding ends in the theca gives a shape of deeply embedded "olfactory bud" which can be commonly observed in the olfactory epithelium of C. carpio (Figs. 14, 27, 29, 30, 31). The dendrites of rod shaped receptor cells also show their rare aggregation (GR. RR.) in the form of an "olfactory bud" on the uniform surface of the olfactory lamellae (Figs. 8, 15, 27, 30). The synaptic contacts in between any of two receptor cells have not been observed any where in the olfactory epithelium of C. carpio and independant identity of each receptor cell is maintained. The axons of all the receptor cells extend proximally and join folium olfactorium (FI. OL. Figs., 17, 20, 22, 23) along basement membrane.

The goblet cells:

These are the dominating cellular components of the olfactory epithelium of C. carpio. They can be easily distinguished in two types : (1) marginal goblet cells (MG.), (2) migratory goblet cells (MIG.). The former are transformed by secondary supporting cells where as latter are the result of the specific basal cells (MU. BC.) lying in the proximal and intervening regions of the lamella adjacent to the raphe.

The marginal goblet cells are seen arranged serially throughout the peripheral surface of the lamella. They are

Fig. 14. Vertical section of lamella of *C. garnia* showing the division of submucosa. Primary nurones are accomodated in crupts. Magnification X 400.

BC.	Basal cell
BCP.	Blood capillary
BM.	Basement membrane
CR.	Crupt
DN. PN.	Dendrite of primary neurone
FI. OL.	Folium olfactorium
MG.	Mega- or marginal goblet cell
MIG.	Micro- or migratory goblet cell
NU. PN.	Nucleus of primary neurone
PN.	Primary neurone
SMSA.	Submucosa
T. SC.	Transitionary supporting cell.

Fig. 15. Transverse section of posterior lamella of *C. garnia* passing through the middle region showing 'olfactory bud', rod shaped receptor cell and empty theca of marginal goblet cells. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
CON. TI.	Connective tissue
DPR.	Depression
FIO OL.	Folium olfactorium
FU. MIG.	Fusion of microgoblet cell
GR. RR.	Grouping of rod shaped receptor cell
MIG.	Micro- or migratory goblet cell
MIV.	Microvilli
OCI.	Olfactory cilia
OLF. BUD	"Olfactory bud"
OV.	Olfactory vesicle
RR.	Rod shaped receptor cell
SR.	Spindle shaped receptor cell
TH. MG.	Theca of marginal goblet cell

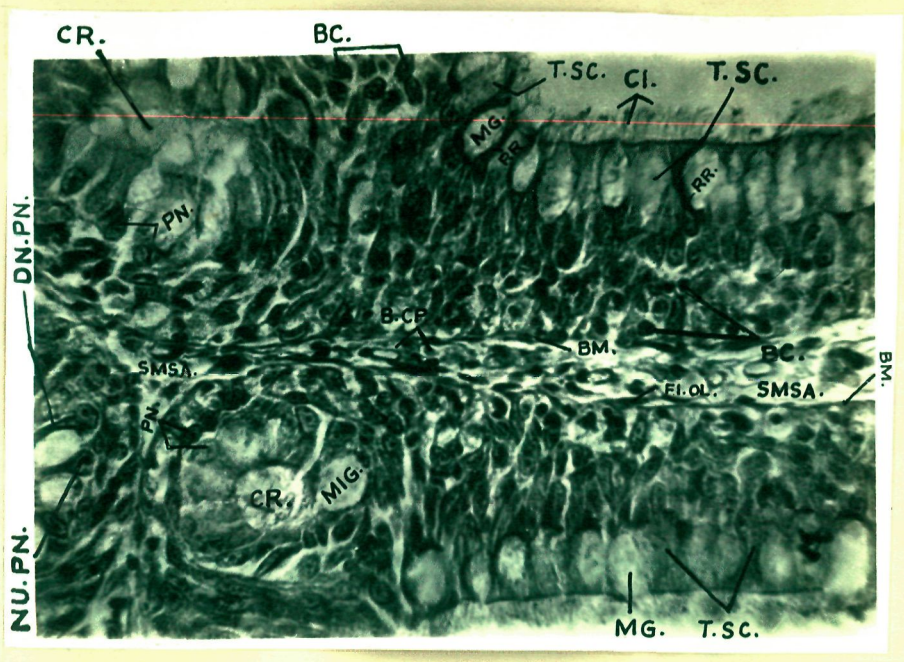

Fig. 14

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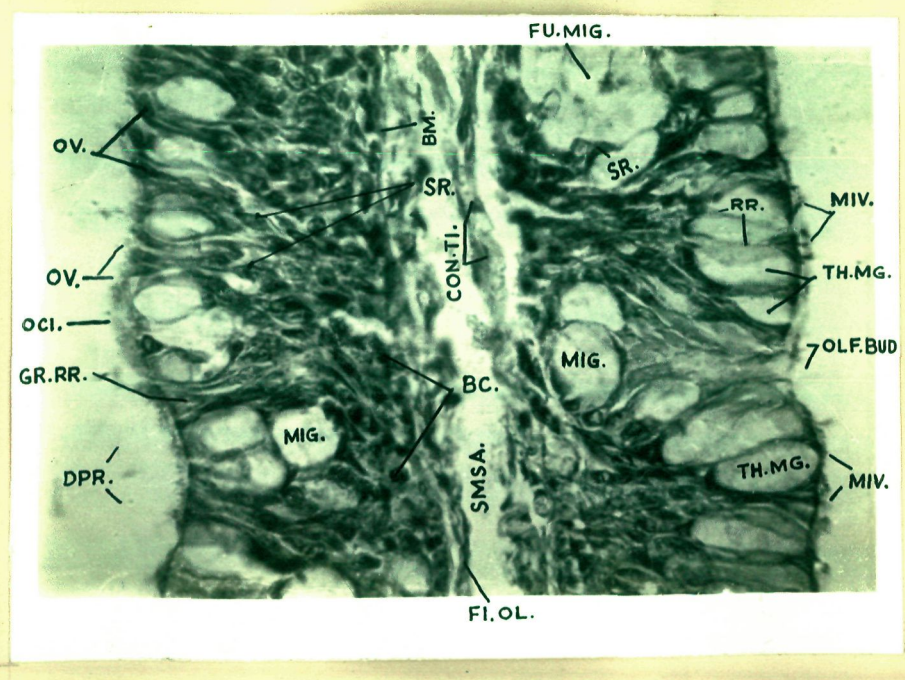

Fig. 15

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Fig. 16. Transverse section of anterior lamella of C. carpio passing through the proximal region. Primary nurones, muciperous basal cells and non-ciliated supporting cell are visible. Magnification X 1000.

BC.	Basal cell
CI.	Cilia
DE. CI. SC.	Distal limb of ciliated supporting cell
DN. PN.	Dendrite of primary nurone
FB. C.	Fibroblast cell
INT. LAM. SP.	Interlamellar space
LYM.	Lymphoide cell
MU. BC.	Muciperous basal cell
NU. PN.	Nucleus of primary nurone
NCI. SC.	Nonciliated supporting cell
SUBM.	Submucosa

Fig. 17. Transverse section of anterior lamella of C. carpio passing through the middle region. Spindle shaped receptor cell, primary nurone and nonciliated supporting cell are visible. Magnification X 1000.

AX. SR.	Axon of spindle shaped receptor cell
AX. PN.	Axon or primary nurone
BC.	Basal cell
CI.	Cilia
CI. SC.	Ciliated supporting cell
DE. CI. SC.	Distal limb of ciliated supporting cell
DN. SR.	Dendrite of spindle shaped receptor cell
INT. LAM. SP.	Interlamellar space
LYM.	Lymphoide cell
NU. SR.	Nucleus of spindle shaped receptor cell
NU NCI. SC.	Nucleus of nonciliated supporting cell
NU. SC.	Nucleus of supporting cell.

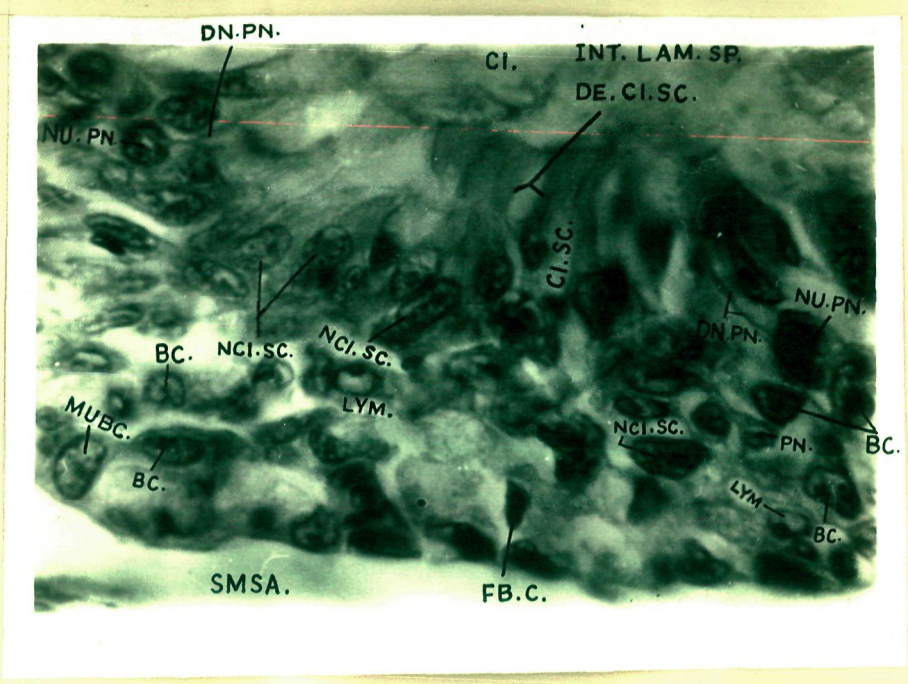

Fig. 16

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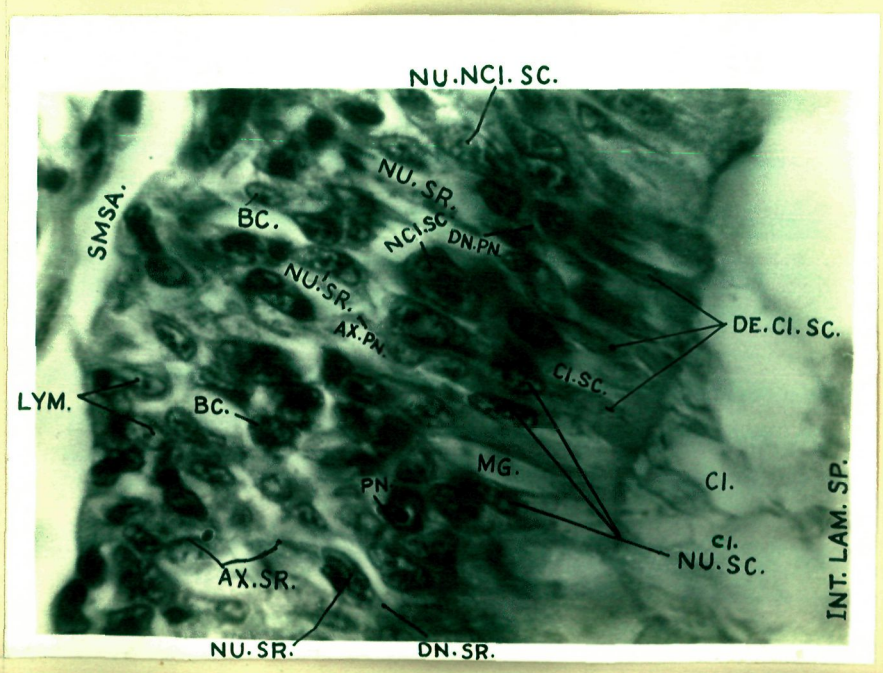

Fig. 17

17

provided with a cup shaped spacious theca (TH. GG.) which is filled with pale droplets of mucigen. The nuclear contents are very much compressed and pushed downwardly leaving a small amount of darkly staining cytoplasm around the nucleus. The nucleus (NU. GG.) and cytoplasmic contents take a triangular shape in which nucleolus and chromatin material is not visible due to the high degree of compression. A stem like proximal limb connects the goblet cell with the basal zone. The rod shaped receptors either lie inbetween the theca of these cells or traverse through the empty theca. The marginal goblet cells are produced continuously with the result of transformation of positively muciperous supporting cells with the age of the fish (Figs. 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22).

The migratory goblet cells (MIG.) originate from the muciperous basal cells (MU. BC.) which are concentrated in the proximal or intervening region of the lamellae adjacent to the raphe (Figs. 10, 16, 18, 19, 20). They are shapeless and usually show rounded structure and remain in wandering tendancy from deeper zones to peripheral zone of the olfactory epithelium. Generally number of newly formed migratory goblet cells are grouped (GR. MIG.) and fused (FU. MIG.) in the form of complicated vacuole like structure (Figs. 26, 32) which gradually grows in size and ultimately burst out from the peripheral surface of the lamella, discharging their mucous

contents in the interlamellar space. This leads to the formation of crupts like formation which may be in the form of depression, flask, funnel and tubular deepenings (Figs. 15, 25, 27, 28, 29, 30, 31). Due to the migratory process of these goblet cells, the olfactory epithelium is affected greatly causing the displacement of basal cells. This results the flow of basal cells in any direction (Figs., 18, 25, 26, 28) which may lead to the formation of hillock elevation, straight projection, bifurcation and trifurcations from the general surface of the olfactory epithelium (Figs. 24, 25, 28, 31).

The grouping and fusion of the goblet cells at some places cause perfect interruption of the olfactory epithelium (Fig. 31). Formation of crupts and microformation amount peculiar findings of this study as nowhere this phenomenon is noticed in the olfactory epithelium of the fishes studied so far.

The basal cells:

The basal cells (BC.) can be distinguished in number of the forms lying irregularly above the basement membrane. The rounded forms of these cells are provided with darkly staining oval nucleus with a clear centrally placed nucleolus and uniformly distributed chromatin materials in karyoplasm. The rounded basal cell can be observed any where in the olfactory

Fig. 18. Transverse section of lamella of *G. carpio* showing the presence of basal cell in the supporting zone indicating their flow from basal zone to supporting zone. Arrows indicate the pathway of flow of basal cell. Magnification X 1000.

BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
DL. CI. SC.	Distal limb of ciliated supporting cell
FB. C.	Fibroblast cell
MU. BC.	Mucipperous basal cell
NCI. SC.	Nonciliated supporting cell
NU. CI. SC.	Nucleus of ciliated supporting cell.

Fig. 19. Transverse section of anterior lamella of *G. carpio* passing through distal region. Marginal goblet cell and spindle shaped receptor cells with their correspondingly elongated axon and dendrites are present. Olfactory vesicle and long olfactory cilia can also be seen. Arrows indicate the pathway of dendrite and axon. Magnification X 1000.

BC.	Basal cell
CI.	Cilia
NU. MG.	Nucleus of marginal goblet cell
NU. SR.	Nucleus of spindle shaped receptor cell
NU. PN.	Nucleus of primary neurone
OV.	Olfactory vessicle
OCI.	Olfactory cilia
TH. MG.	Theca of magrinal goblet cell
T. SC.	Transitionary supporting cell

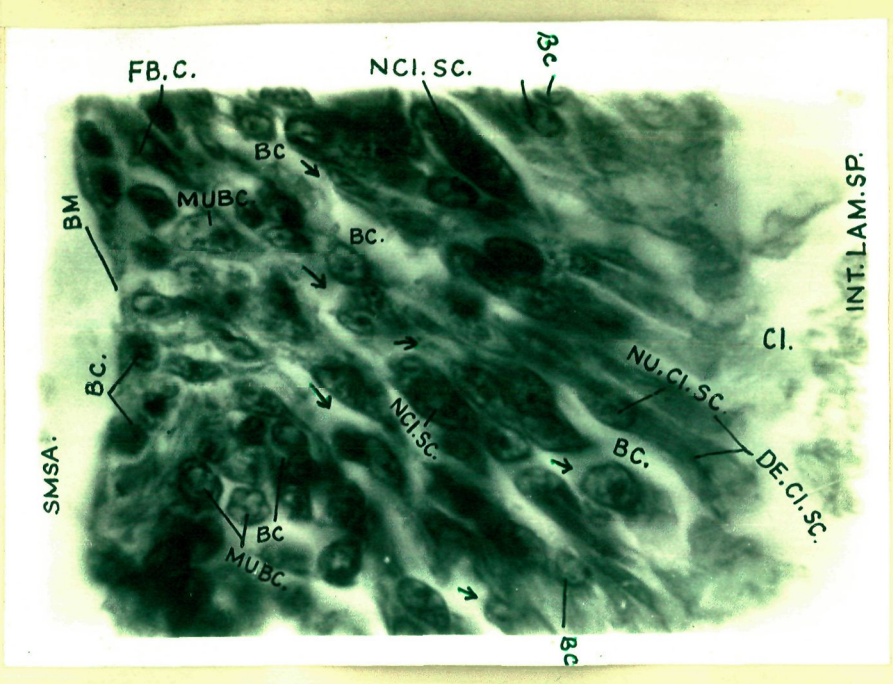

Fig. 18

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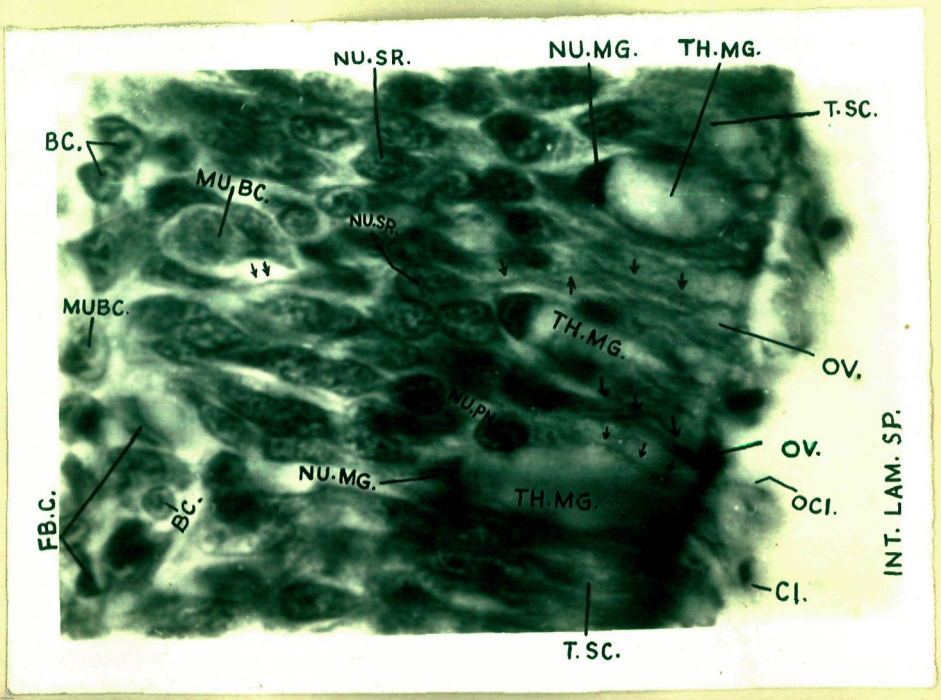

Fig. 19

19

Fig. 20. Transverse section of the middle lamella of *C. garzia* passing through the middle region. Peripheral surface of lamella is occupied by the theca of goblet cell with the presence of rod shaped receptor cell in between them. Rod spindle shaped receptor cell and olfactory vesicle with microvilli are visible. Arrows indicate the pathways of axon. Magnification X 1000.

AX.	Axon
AX. SR.	Axon of spindle shaped receptor cell
DN. RR.	Dendrite of rod shaped receptor cell
MG.	Marginal goblet cell
MU. BC.	Muciperous basal cell
MVI.	Microvilli
NCI. SC.	Nonciliated supporting cell
NU. RR.	Nucleus of rod shaped receptor cell
NU. SR.	Nucleus of spindle shaped receptor cell
OV.	Olfactory vesicle
PN.	Primary neurone

Fig. 21. Transverse section of posterior lamella of *C. garzia* showing dendrite of rod shaped receptor cell in between the theca of two goblet cell which ends on the free surface of lamella in the form of olfactory vesicle. Microgoblet cell and spindle shaped receptor cell are also visible. Arrows indicate the path way axon and dendrite. MagnificationX1000.

DN. RR.	Dendrite of rod rshaped receptor cell
NU. MG.	Nucleus of marginal goblet cell
NU.PN.	Nucleus of primary neurone
NU. MIG.	Nucleus of microgoblets
NU. RR.	Nucleus of rod shaped receptors
NU. SR.	Nucleus of spindle shaped receptor cell
OCI.	Olfactory cilia

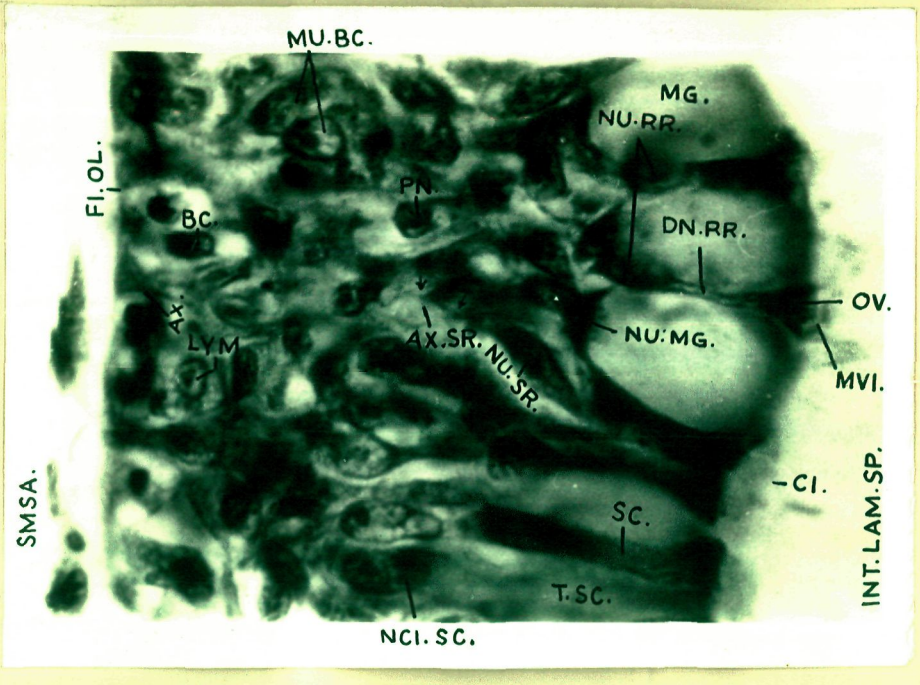

Fig. 20

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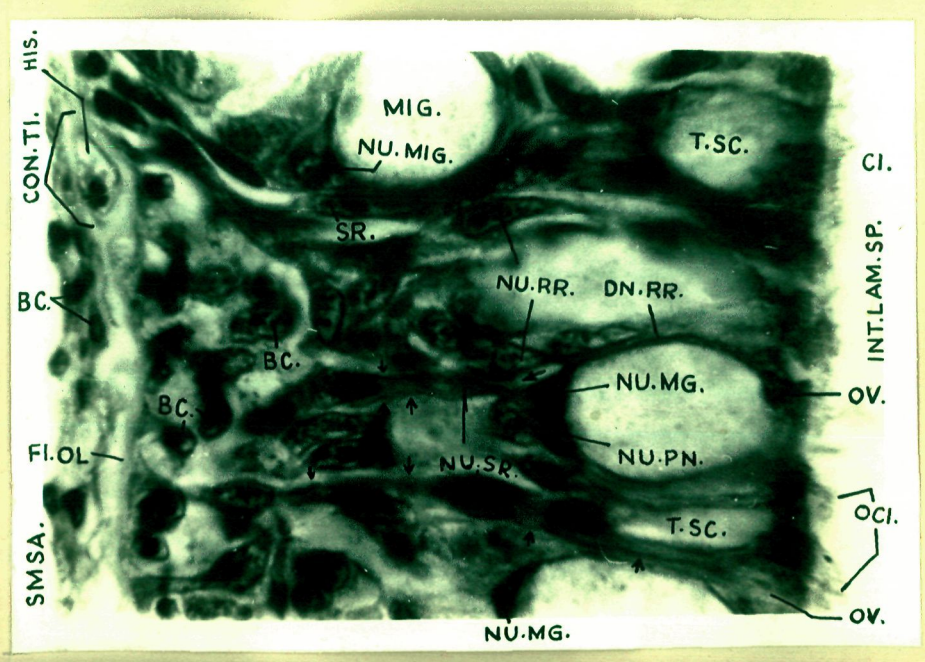

Fig. 21

21

epithelium. They are found distributed even in the extreme peripheral zone (Figs. 18, 28, 29, 32) among the dendrites of receptors and distal limbs of the supporting cells. Their aggregation (GR. BC.) in groups can be commonly observed in the olfactory epithelium of C. carpio (Figs. 22, 27, 29, 33) which may be the initial preparation, leading to microformations in the surface of lamella. The larger form of the basal cell (MU. BC.) is observed uniformly distributed above the basement membrane in proximal and intervening regions of the olfactory epithelium of anterior lamellae (MU. BC., Figs. 10, 16, 18, 19, 20, 23). These (MU. BC.) are filled with highly mucoserous cytoplasm which pushed the nuclear and cytoplasmic contents to the extreme inner side to give rise migratory goblet cell. These basal cells are migratory form and show their shifting from proximal zone to the peripheral zone (Figs. 18, 25) giving rise to the crupts and microformations (Figs. 18, 24, 25, 26, 28, 30, 32).

Fibroblast cells (FB. C., Figs. 16, 18, 22, 23) and irregular lymphoid cells (LYM., Figs. 16, 17, 20) can also be observed in the basal zone (BC. Z.).

The central core or submucosa:

The central core or submucosa (SMSA.) is lined on either side by the basement membrane (BM). It is made up of dense collagen fibre connective tissue which lies intengled in

Fig. 22. Transverse section of lamella of C. carpio passing through thicker region of olfactory epithelium and showing the presence of correspondingly elongated axon and dendrites. Grouping of basal cells are visible. Arrows indicate the pathways of dendrite and axon. Magnification X 1000.

BC.	Basal cell
CI.	Cilia
CON. TI.	Connective tissue
DE. CI. SC.	Distal limb of ciliated supporting cell
FB. C.	Fibroblast cell
HIS.	Histocytes
NU. MG.	Nucleus of marginal goblet cell
NU. SR.	Nucleus of spindle shaped receptor cell
PIG. C.	Pigment cell
PN.	Primary neurone
SR.	Spindle shaped receptor cell

Fig. 23. Transverse section of lamella of C. carpio passing through the submucosa of anterior lamella. Fibroblasts and pigment cells are intengled in collagen fibres. Magnification X 1000.

BC.	Basal cell
BM.	Basement membrane
COL. FI.	Collagen fibres
CON. TI.	Connective tissue
MSA.	Mucosa
MU..BC.	Muciperous basal cell
PIG. C.	Pigment cell.

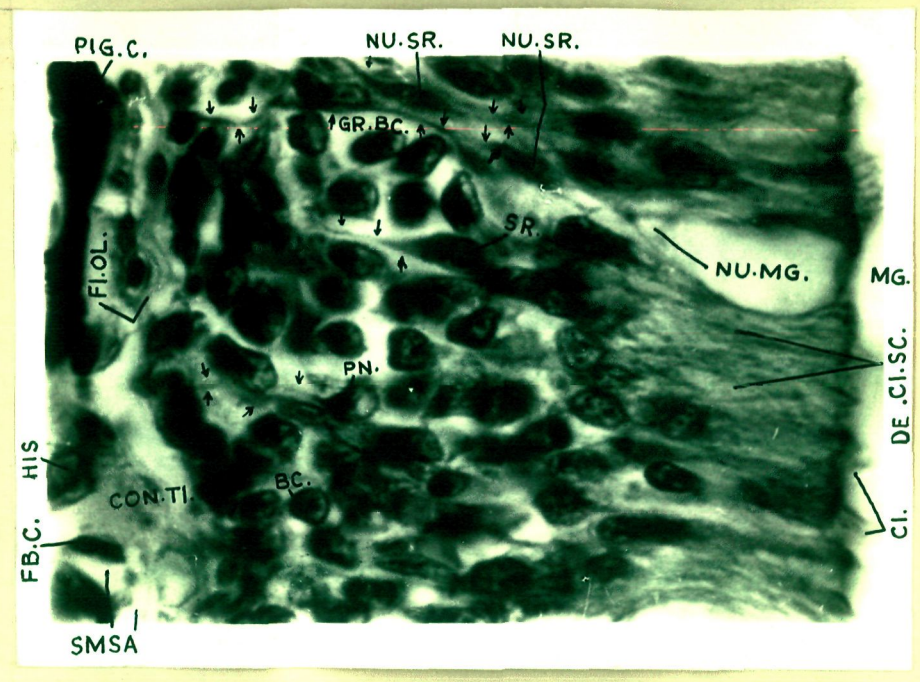

Fig. 22

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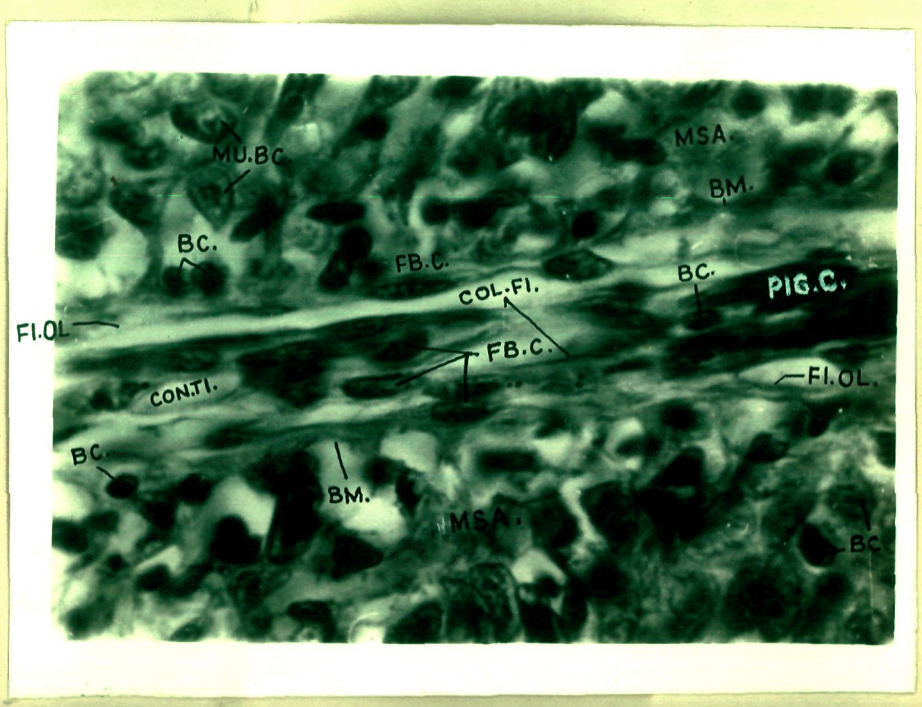

Fig. 23

23

Fig. 24. Vertical section of lamella of C. carpio. The formation of micro- or migratory basal cell caused the formation of hillock elevation. Foreign material intengled in mucous can be seen in the interlamellar space. Magnification X 400.

BC.	Basal cell
BC. Z.	Basal zone
CI. SC.	Ciliated supporting cell
HIL. EL.	Hillock elevation
MG.	Mega- or marginal goblet cell
MIG.	Micro- or migratory goblet cell
MU. FGN.	Foreign material intengled in mucous
SC. Z.	Supporting zone.

Fig. 25. Vertical section of lamella of C. carpio showing displacement of basal cell due to the formation of microgoblet cell at the variable depths of mucosa. This result the formation of hillock elevations and depression. Arrows indicate the flow of basal cells. Magnification X 400.

BC.	Basal cell
BC. Z.	Basal zone
DPR.	Depression
HIL. EL.	Hillock elevation
LAM.	Lamella
MG.	Marginal goblet cell
MIG.	Microgoblet cell

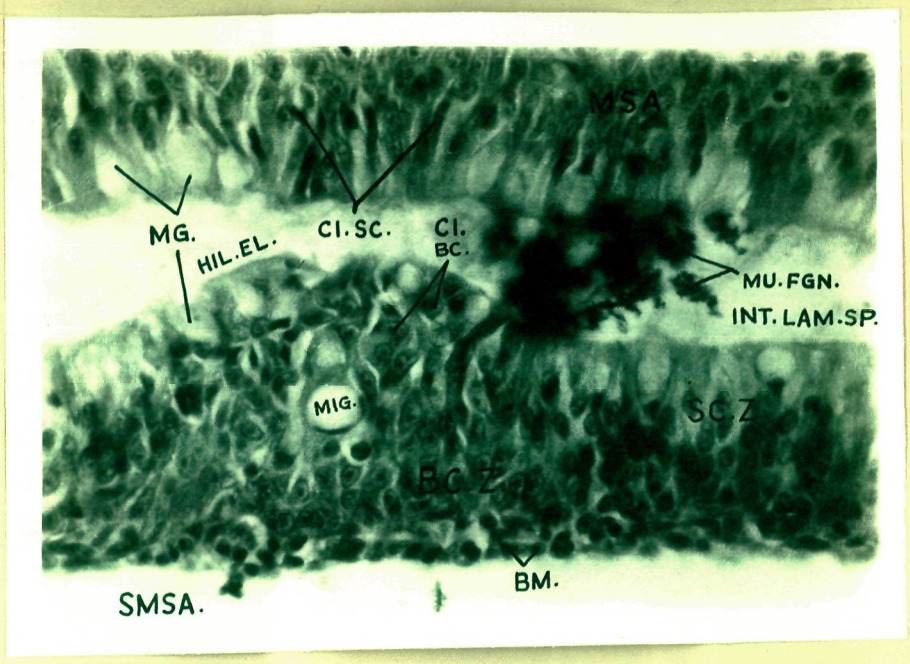

Fig. 24

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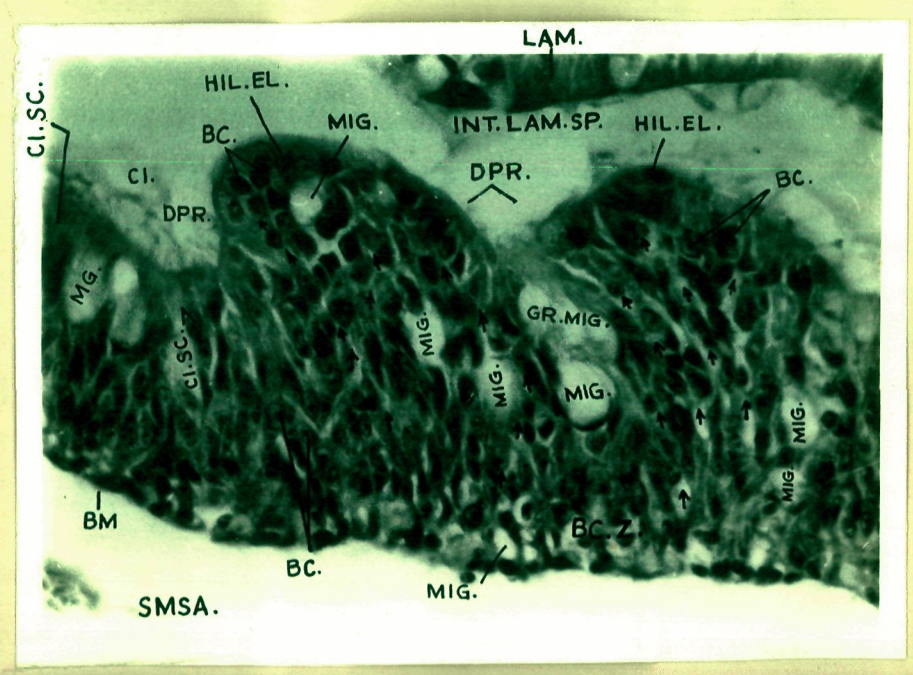

Fig. 25

25

Fig. 26. Vertical section of the lamella of C. carpio showing grouping and fusion of large number of micro- or migratory goblet cell which occupy a large space in the mucosa, causing the displacement of basal cells of underlying basal zone. Arrows indicate the flow of basal cells. Magnification X 400.

BC.	Basal cell
BC. Z.	Basal zone
CI.	Cilia
FU. MIG.	Fusion of microgoblet cell
INT. LAM. SP.	Interlamellar space
MG.	Marginal goblet cell
MIG.	Microgoblet cell
MU. BC.	Muciperous basal cell
T. SC.	Transitionary supporting cell

Fig. 27. Vertical section of lamella of C. carpio where grouping, fusion and subsequent bursting of large number of goblet cell from the general surface of lamella cause the formation of crupt. The dendrite protrude in the lumen of crupt giving it a shape of "olfactory bud". Rod shaped receptor cell are visible in groups. Magnification X 400.

BC.	Basal cell
BC. Z.	Basal zone
DN. RR.	Dendrite of rod shaped receptor cell
DN. PN.	Dendrite of primary neurone
DN. RC.	Dendrite of receptor cell
GR. RR.	Group of red shaped receptor cell
MG.	Marginal goblet cell
MIG.	Microgoblet cell.

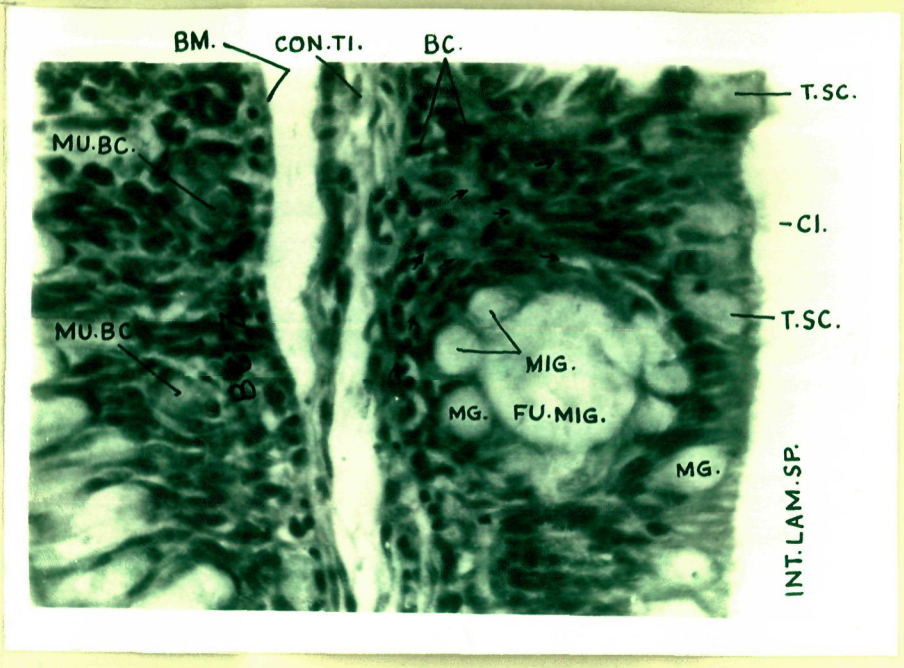

Fig. 26

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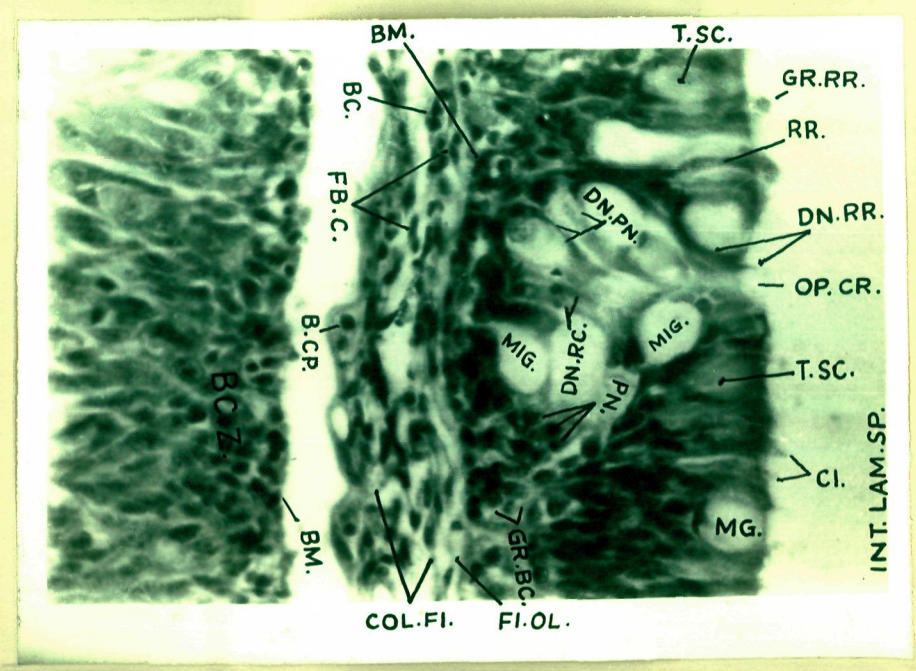

Fig. 27

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Fig. 28. Vertical section of lamella of C. carpio showing hillock elevations and flow of basal cells to the free surface of lamella. Arrows indicate the flow of basal cell. Magnification X 400.

B.M.	Basement membrane
CI. SC.	Ciliated supporting cell
DPR.	Depression
GR. BC.	Group of basal cell
HIL. EL.	Hillock elevation
INT. LAM. SC.	Interlamellar space
MG.	Marginal goblet cell
MIG.	Microgoblet cell
T. BC.	Transitionary basal cell

Fig. 29. Vertical section of lamella of C. carpio showing funnel shaped crupt where large number of primary neurones are accomodated. Grouping of basal cells are visible. Magnification X 400.

BC. Z.	Basal zone
BM.	Basement membrane
CI. SC.	Ciliated supporting cell
FU. MIG.	Fusion of microgoblet cell
GR. BC.	Grouping of basal cell
INT. LAM. SP.	Interlamellar space
OCI.	Olfactory cilia
PN.	Primary neurone

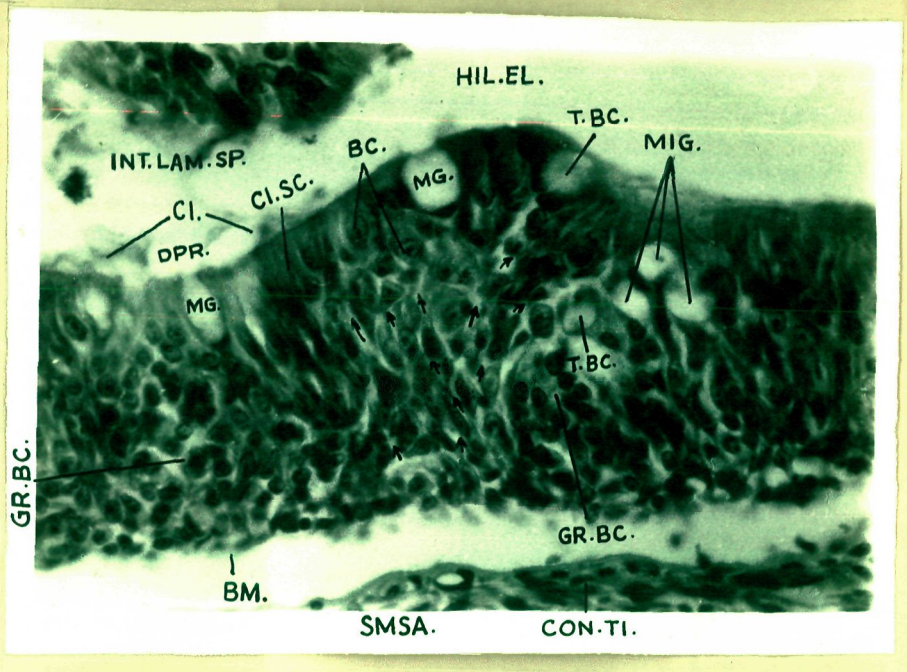

Fig. 28

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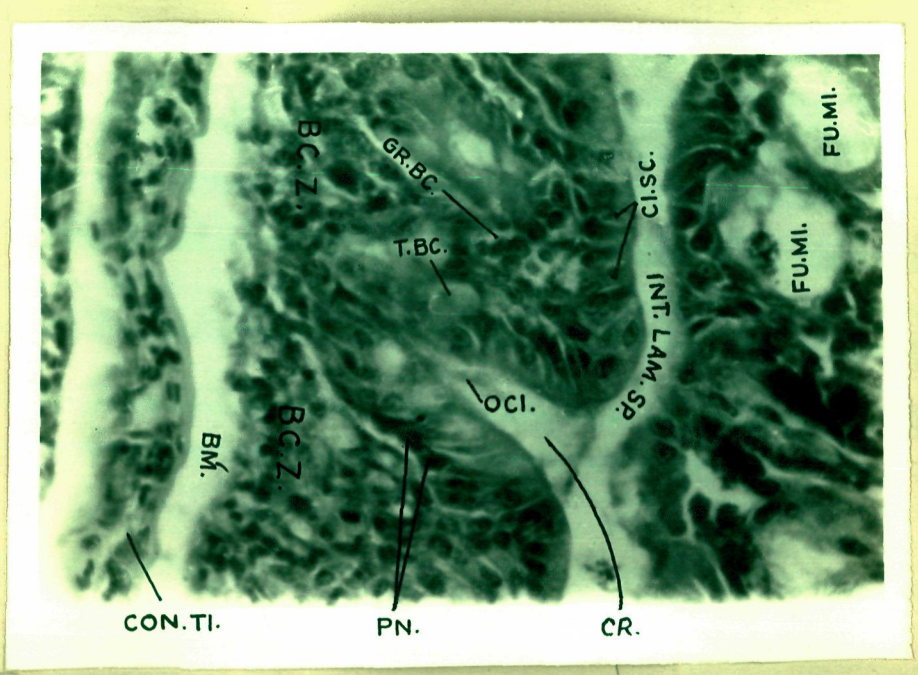

Fig. 29

CR

29

matrix (Fig. 33). The presence of branched fibroblasts (FB. C.), histocytes (HIS.), basal cells (BC.) and pigment cells (PIG. C.) are also noticed in the submucosa of C. carpio (Figs. 11, 15, 21, 22, 23, 33). Only folium olfactorium (FIL. OL.) fibres run along the basement membrane and which join the nonmedullated nerve fibres (NMN. FI.) at raphe (Fig. 35). The blood supply is in form of finner blood capillaries (BC., Figs. 14, 27, 30, 32) and blood sinus (BL. SI., Fig. 34) passes through the raphe. Thick collagen bundles (COL. FIB.) are lying in the central core which entangles branched pigment cells. The connective tissue lying the submucosa is compact and no areolae are seen (Figs. 14, 15, 22, 23, 26, 27, 33). It is in continuation with the submucosa of raphe (Figs. 9, 34). Thick collagen fibres provide strength to the lamellae forming a turger like structure. The branching of submucosa is observed at the terminal bifurcations and trifurcations (Figs. 12, 13, 14), but in other places it remains uniform and no offshoot formation is observed in the other microformation.

The raphe:

The raphe is nonciliated, nonsensory and median thickening of olfactory floor which allow the attachment of all the lamellae on its either sides (Figs. 9, 34). It is composed of a speceous central core or submucosa (SMSA.) with dense

Fig. 30. Vertical section of lamella of C. carpio showing flask shaped crupt, where dendrite or primary neurone projects. Magnification X 400.

ARE.	Areolae
BC.	Basal cell
CI. SC.	Ciliated supporting cell
CR.	Crupt.
DN. PN.	Dendrite of primary neurone
DN. RR.	Dendrite of rod shaped receptor cell
GR. RR.	Grouping of rod shaped receptor cell
HIS.	Histocytes
MG.	Marginal goblet cell
MIG.	Microgoblet cell
OP. CR.	Opening of crupt
RR.	Rod shaped receptor cell.

Fig. 31. Vertical section of lamella of C. carpio showing complete interruption of olfactory epithelium due to the formation of large number of crupts which allow numerous receptor cells. Straight projections are visible. Arrows indicate the flow of basal cells. Magnification X 400.

BM.	Basement membrane
CI.SC.	Ciliated supporting cell
CR.	Crupt
DN. PN.	Dendrite of primary neurone
DN. RR.	Dendrite of rod shaped receptor cell
FU. MIG.	Fusion of microgoblet cell
INTR. OLF. EPI.	Interruption of olfactory epithelium.
MIG.	Microgoblet cell
PN.	Primary neurone
STR. PJ.	Straight projection.

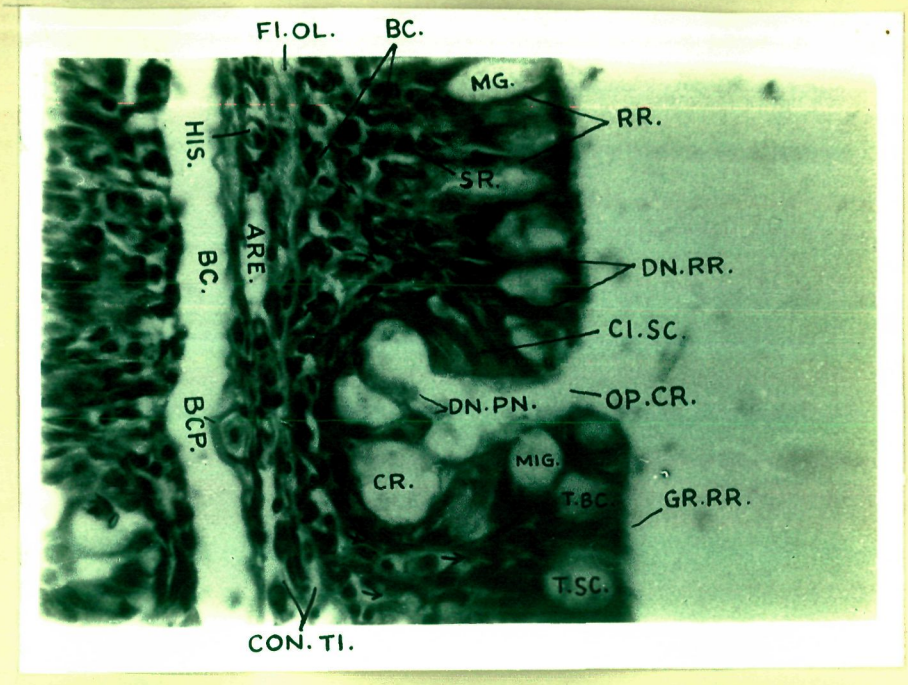

Fig. 30

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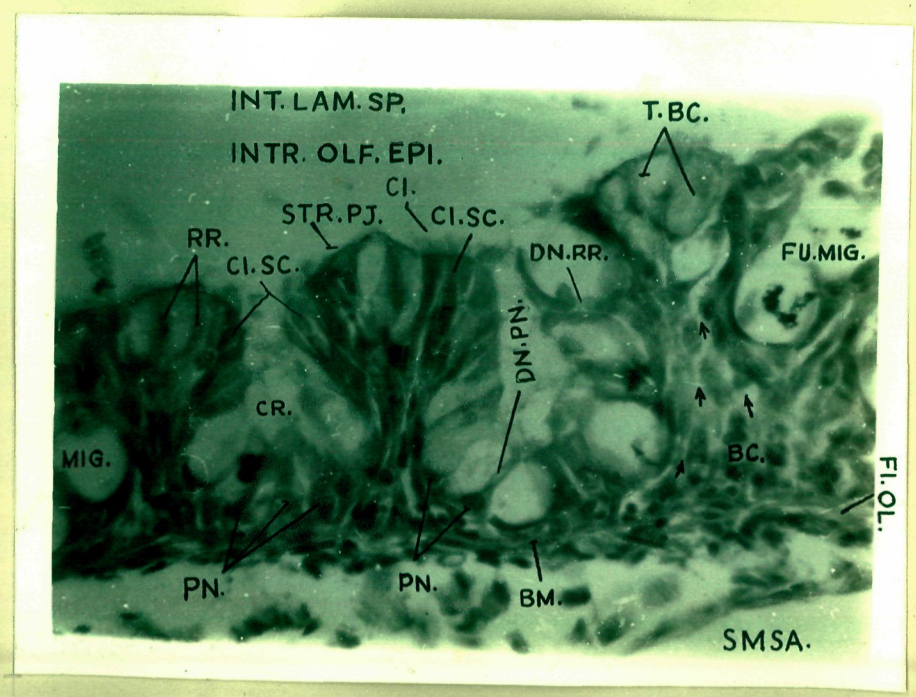

Fig. 31

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Fig. 32. Vertical section of lamella of C. carpio showing complete fusion of numerous micro- or migratory goblet cells forming a rounded vacuole like structure, causing the displacement of basal cells. Arrows indicate the flow of basal cells. Magnification X 400.

BC.	Basal Cell
CI.	Cilia
CI. SC.	Ciliated supporting cell
FU. MIG.	Fusion of microgoblet cell
MG.	Marginal goblet cell
MIG.	Microgoblet cell.

Fig. 33. Transverse section of lamella of C. carpio passing through the submucosa showing branched fibroblast cells and grouping of basal cell in mucosa. Magnification X 1000.

BC.	Basal cell
COL. FI.	Collagen fibres
FB. C.	Fibroblast cell
GR. BC.	Grouping of basal cell
HIS.	Histocytes.

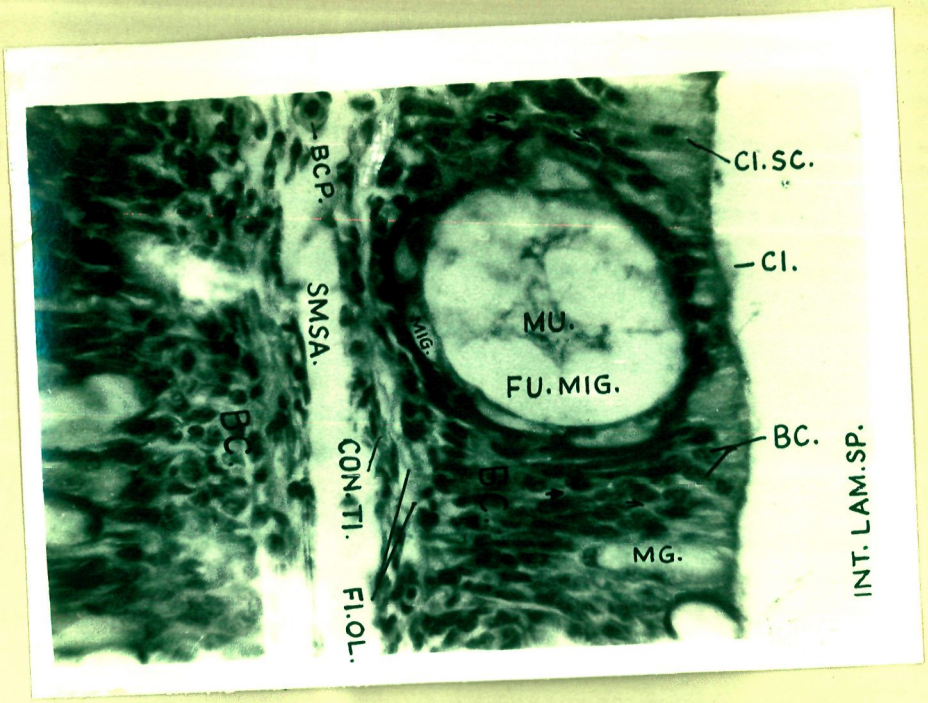

Fig. 32

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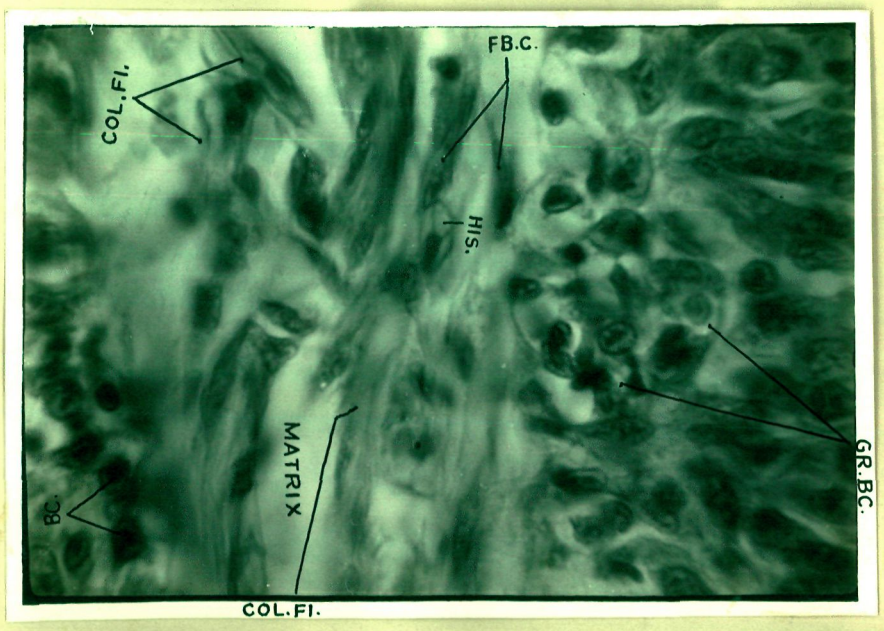

Fig. 33

33

Fig. 34. *Transverse section of rosette of* G. *sarcia passing through the raphe.* Magnification X 100.

ARE.	Areolae
B. SI.	Blood sinus
COL. FI.	Collagen fibre
CON. TI.	Connective tissue
LAM.	Lamella
SMSA.	Submucosa.

Fig. 35. Transverse section passing through raphe of G. sarcia. Peripheral surface of the raphe is occupied by the theca of goblet cells. Magnification X 400.

BC.	Basal cell
BC. Z.	Basal zone
COL. FI.	Collagen fibre
CU. SC.	Cuboidal supporting cell
DE. SC.	Distal limb of supporting cell
FB. C.	Fibroblast cell
HIS.	Histocytes
NMN. FI.	Nonmedullated nerve fibre bundle
MU.	Mucous
TH. MG.	Theca of marginal goblet cell.

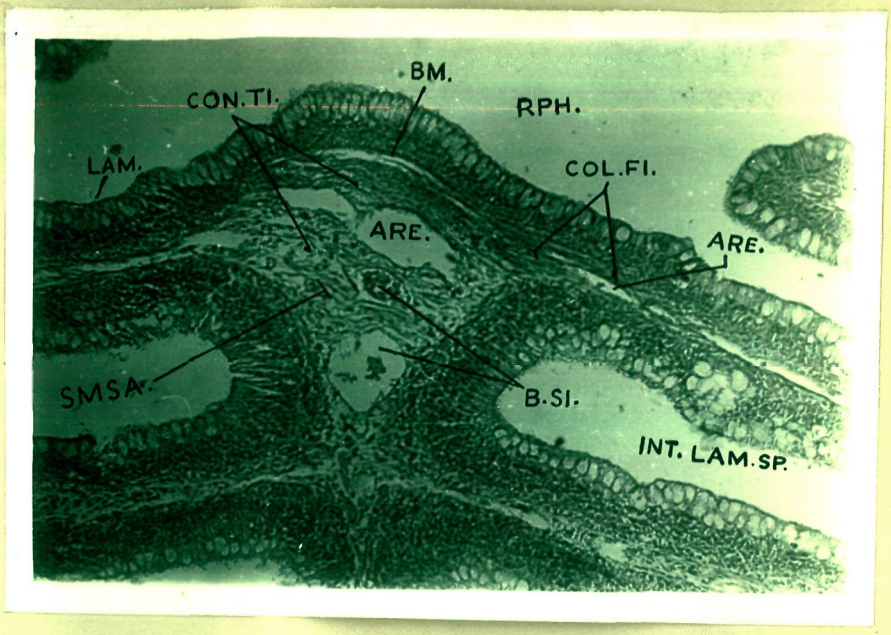

Fig. 34

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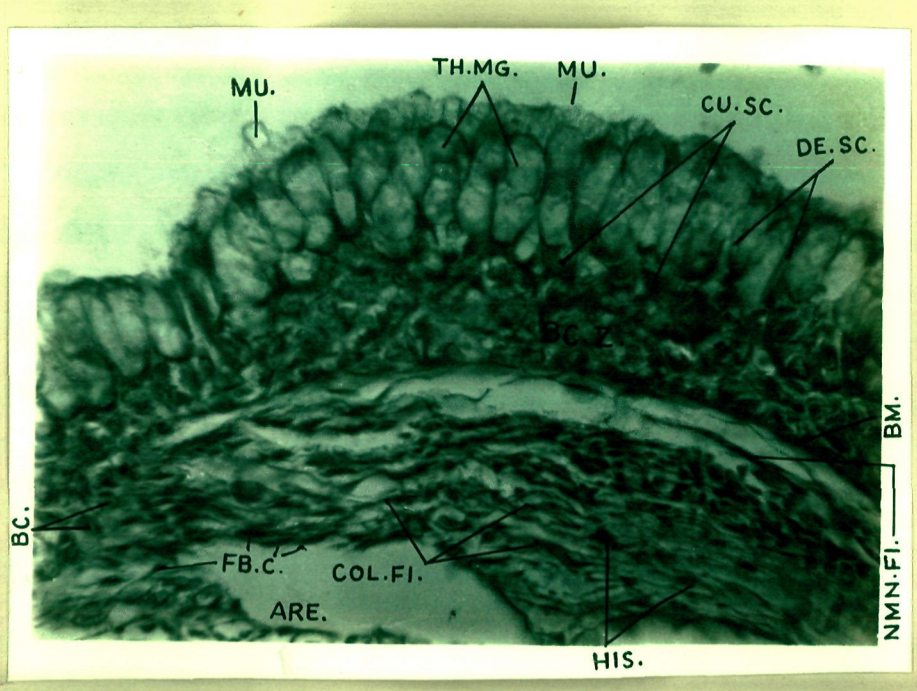


Fig. 35

35

collagen fibres, basal cells, fibroblasts and histocytes cells submerged in thick matrix. Two rounded areolae (ARE.) and central blood sinus (BL. SI.) are seen in the submucosa of the raphe of *C. carpio*. Nonmedulated nerve fibres extend along the basement membrane and join the folium olfactorium coming from lamellar regions. The mucosa of raphe is made up of cuboidal epithelium, consists of cuboidal supporting cells (CU. SC.), marginal goblet cells (MG.) and basal cells. The margin of the raphe is totally occupied by the cup shaped theca (TH. MG.) of the goblet cells which is outwardly or distally covered by mucous sheath (MU.) secreted by these cells. Below the goblet cells lie one or two layers thick cuboidal cells whose distal processess extend upto the distal surface of the raphe. They have rounded darkly staining nuclei. The basal zone is three to five layer thick, lying in regular rows just above the basement membrane. The submucosa and mucosa of the raphe is in continuation with the lamellae. The nervous and neutritional supply in the lamellae is through raphe (Figs., 9, 10, 35).

ANATOMICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *HETEROPNEUSTES FOSSILIS* (BLOCH)

H. fossilis bears a pair of olfactory chambers on the dorsal surface of the head, lying close to the snout and away from the eye orbit (Figs. 36, 38A). They are ventilated out side by a pair of openings which can be named as anterior and posterior nasal openings (ANT. NAS. OP. AND POST. NAS. OP.) with regards to their respective position. Both the openings are placed at a distance of 5 mm from each other and demarcate two extremities of the olfactory chamber. The anterior nasal opening is tubular (ANT. NAS. TUBE) over hanging on the upper lip while posterior is valvular and flush with surface of the head (Figs. 36, 38A). The latter is in the form of an oblique furrow surrounded by the loose cresentric area of the integument and is made of anterior and posterior lips of the skin (ANT. LIP AND POST. LIP, Fig. 38D). The former gets expanded over the latter giving a shape of valve to the posterior nasal opening which regulates the entry and exit of water current through the olfactory chamber. Anterior to the posterior nasal opening lies a nasal barble (NAS. BAR., Fig. 36, 38A, 38B) whose movement causes effective variation in the volume of the olfactory chambers. It is (olfactory chamber) enormously developed with a leaf shaped appearance accomodating the rosette (RE.) and the accessory sac (VEN. LAT. ACC. NAS. SAC)

Fig. 36. Dorsal view of the head of H. fossilis.

ANT. NAS. OP. - Anterior nasal opening
NAS. BAR. - Nasal barble
POST. NAS. OP. - Posterior nasal opening

Fig. 37. Dissection of the head of H. fossilis from dorsal side to show rosette insitu.

CEN. CH. - Central channel
ETH. H. - Ethmoidal half
LAC. H. - Lacrymal half
LAM. LESS AREA - Lamellae-less area
LING. - Linguiform process
PER. CH. - Peripheral channel
RPH. - Raphe
VEN. LAT. ACC. SAC. - Ventro-lateral accessory sac
W. OLF. CHAM. - Wall of olfactory chamber.

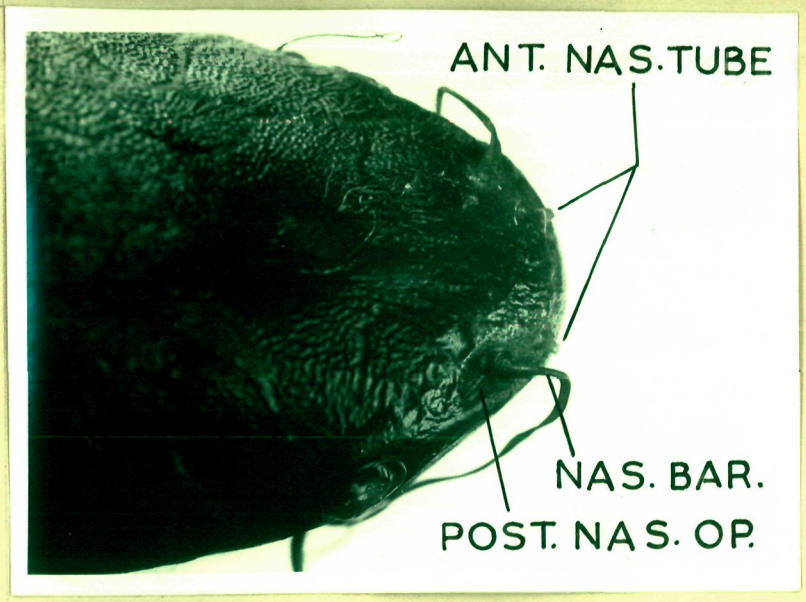

ANT. NAS. TUBE
NAS. BAR.
POST. NAS. OP.

Fig. 36


ETH. H.
W. OLF. CHAM.
RPH.
PER. CH.
LAM. LESS AREA
CEN. CH.
VEN. LAT. ACC. SAC.
LING
LAC. H.

Fig. 37

Fig. 38A. Diagram of Dorsal view of the head of H. *fossilis*.

Fig. 38B. Magnified diagram of the posterior nasal opening with nasal barble of H. *fossilis*.

Fig. 38C. Diagram of anterior nasal tube to show the position of anterior nasal opening.in H. *fossilis*.

Fig. 38D. Diagramatic sketch of the rosette with ventro-lateral accessory nasal sac.

Fig. 38E. A set of 1-32 lamellae from one half of the rosette.

ANT.	-	Anterior
ANT. LIP	-	Anterior lip
ANT. NAS. OP.	-	Anterior nasal opening
ANT. NAS. TUBE	-	Anterior nasal tube
CEN. CH.	-	Central channel
ETH. H.	-	Ethmoidal half
LAC. H.	-	Lacrymal half
LAM.	-	Lamella
LAM. LESS AREA	-	Lamellae-less area
NAS. BAR.	-	Nasal barble
OP. ACC. SAC.	-	Opening of accessory sac
PER. CH.	-	Peripheral channel
POST.	-	Posterior
POST. LIP	-	Posterior lip
POST. NAS. OP.	-	Posterior nasal opening
RPH.	-	Raphe
W. OLF. CHAM.	-	Wall of olfactory chamber.

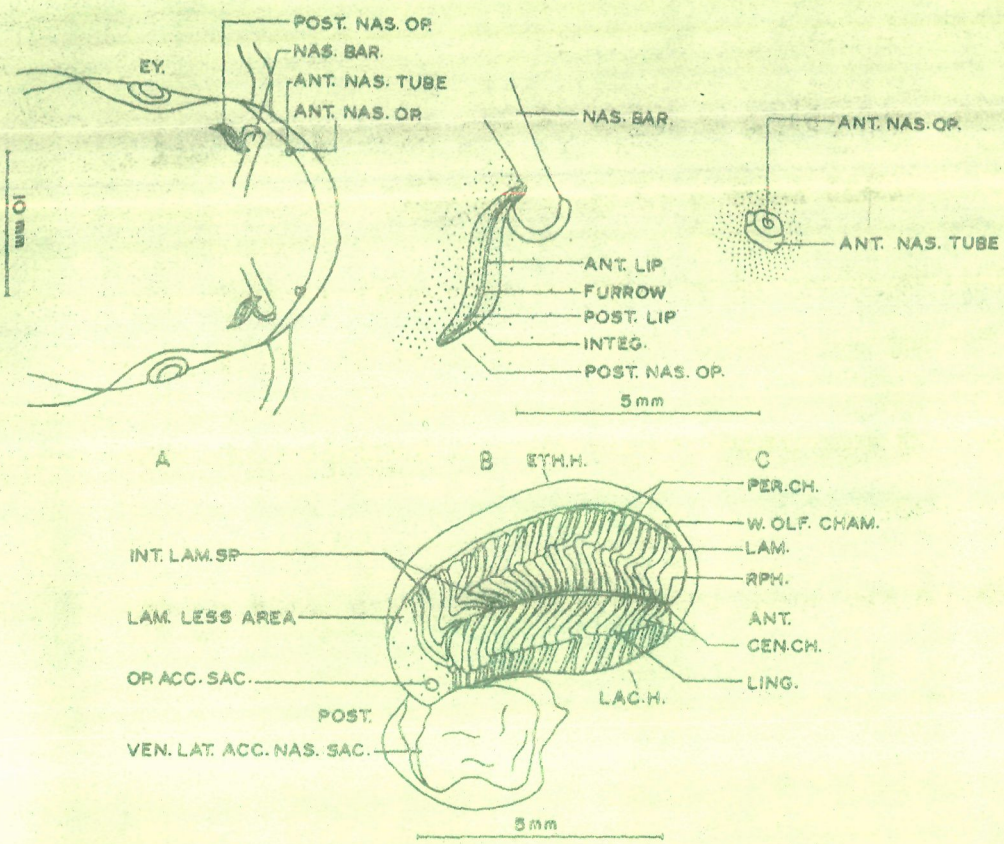
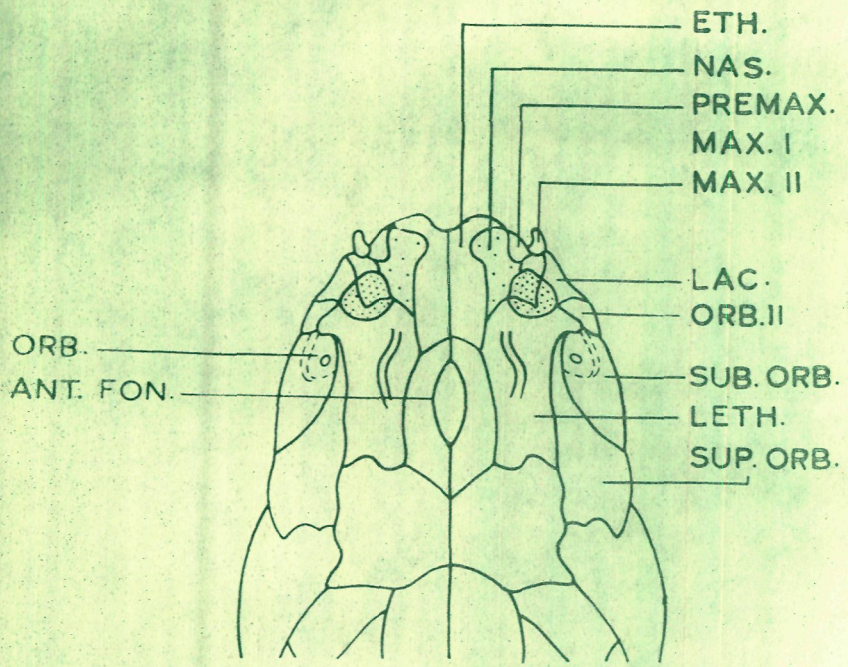

POST. NAS. OP.
NAS. BAR.
EY.
ANT. NAS. TUBE
ANT. NAS. OR
10 mm
NAS. BAR.
ANT. NAS. OP.
ANT. NAS. TUBE
ANT. LIP
FURROW
POST. LIP
INTEG.
POST. NAS. OP.
5 mm
A
B
ETH. H.
C
PER. CH.
W. OLF. CHAM.
LAM.
RPH.
ANT.
CEN. CH.
LING.
LAC. H.
INT. LAM. SP.
LAM. LESS AREA
OR. ACC. SAC.
POST.
VEN. LAT. ACC. NAS. SAC.
5 mm
D
1
11
12
18
19
25
26
32
5 mm
E

FIG. 38

Fig. 39A. Dorsal view of skull of H. fossilis (Posterior region is not drawn).

Fig. 39B. Ethmoidal region of the skull after removing ethmoid and nasal bones to show the floor of olfactory chamber in H. fossilis.

ANT. FON.	-	Anterior fontenallae
ETH.	-	Ethmoid
LAC.	-	Lacrymal
LETH.	-	Lateral ethmoid
MAX.I	-	Maxilla I
MAX. II	-	Maxilla II
NAS.	-	Nasal
ORB.	-	Orbit
ORB. II	-	Orbital II
PAL.	-	Palatine
PRMAX.	-	Premaxilla
SUB. ORB.	-	Suborbital
SUP. ORP.	-	Supraorbital
VEN. PAD. LETH.	-	Ventral pad of lateral ethmoid
VOM.	-	Vomer.


ETH.
NAS.
PREMAX.
MAX. I
MAX. II
LAC.
ORB.II
ORB.
ANT. FON.
SUB. ORB.
LETH.
SUP. ORB.
10 mm
A

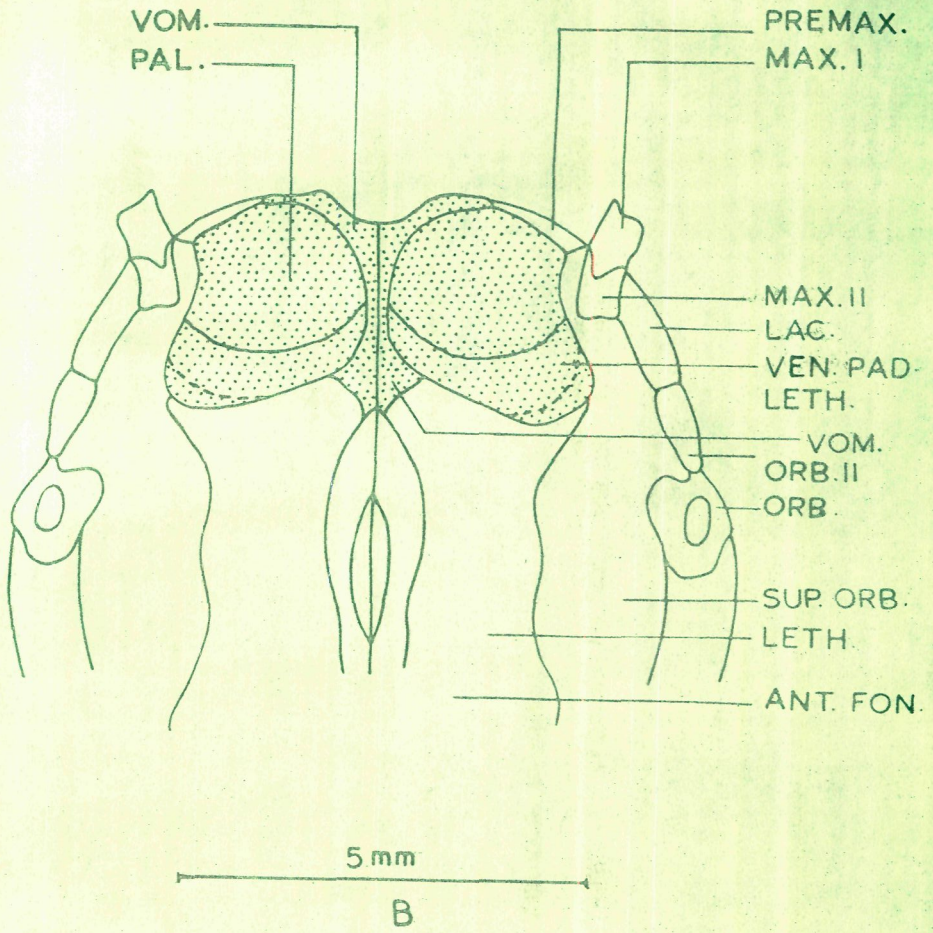

VOM.
PAL.
PREMAX.
MAX. I
MAX. II
LAC.
VEN. PAD.
LETH.
VOM.
ORB.II
ORB.
SUP. ORB.
LETH.
ANT. FON.
5 mm
B

FIG. 39

Fig. 40. Diagram of the dissection of the head of H. fossilis from dorsal side to show the relationship of brain with the rosette.

CE.	-	Cerebellum
EY.	-	Eye
OLF. BL.	-	Olfactory bulb
OLF. LO.	-	Olfactory lobe
OLF. TR.	-	Olfactory tract
RE.	-	Rosette
VEN. LAT. ACC. SAC.	-	Ventro-lateral accessory nasal sac.

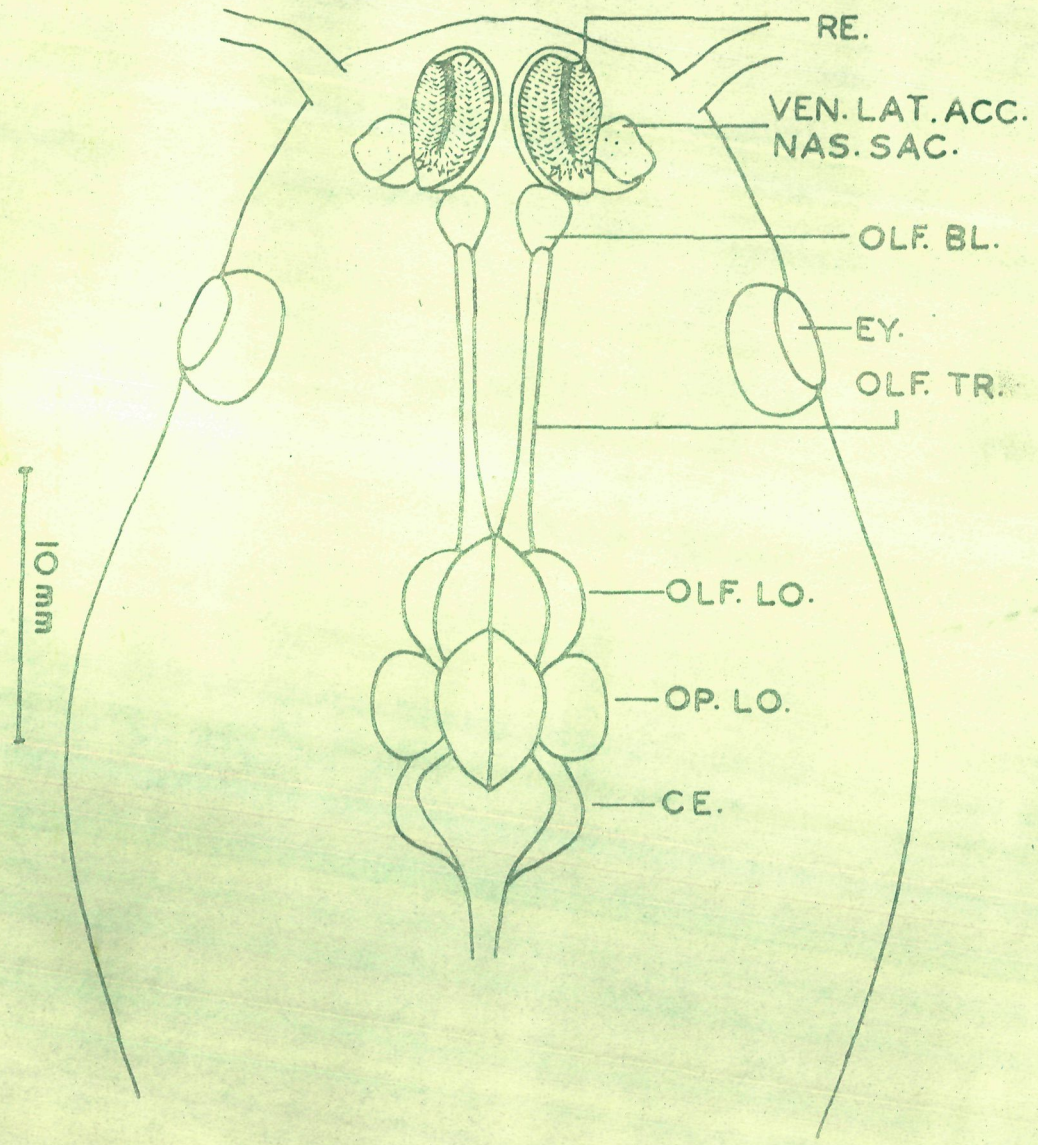


FIG. 40.

lying median and ventro-lateral in positions respectively (Figs. 37, 38D). With respect to the position, the sac is named as ventro-lateral accessory nasal sac which lies just near to postero-lateral extremity of the olfactory chamber in continuation with the olfactory epithelium (a. OLF. CHA., Figs. 37, 38D) of the rosette. It is roughly rounded and is lined by numerous irregular layers which opens by an independent aperture (OP. ACC. SAC) in the posterior most part of the olfactory chamber, just below the posterior nasal opening (Fig. 38D).

In a fish of 270 mm total length, the olfactory chamber is situated at a distance of 2 mm from the snout and 5 mm from eye orbit. The distance between the anterior and posterior nasal opening is 5 mm. The anterior tube is 2 mm in length having an anterior nasal opening 0.234 mm in diameter. The width of posterior nasal opening is 2.5 mm and lies obliquely 10 mm in length.

The olfactory rosette (*RE.*) is leaf shaped and elongated structure having anterior broad and posterior narrow ends (Figs. 37, 38D, 40). It consists of thick olfactory epithelium and gives rise to numerous lamellae (LAM.) attached on either sides of the raphe (RPH., Figs. 37, 38D, 50, 51). Each rosette is divided into an ethmoidal and lacrymal halves (ETH. H. AND LAC. H., Figs. 37, 38D) by an antero-posteriorly extended

narrow raphe. The rosette is almost flat and is attached with the floor of the olfactory chamber by fibrous connective tissue. The peripheral and central channels (PER. CH. AND CEN. CH.) are present in each halves of the rosette and continuous antero-posteriorly ascending series of linguiform process (LING.) stand as partition in between them. The posterior extremity of the olfactory rosette is narrow and lamellae less (LAM. LESS AREA) where the accessory sac opens by an independent aperture (Figs. 37, 38D).

The lamellae (LAM.) of H. fossilis are short and broad which are attached proximally with the raphe and distally with the wall of the olfactory chamber (Figs. 37, 38D). Their dorsal surface is free and maintains inter-lamellar space (INT. LAM. SP., Figs. 38D, 50, 51) in between them. The dorsal medial surface of each lamella is projected out in the form of a thumb like linguiform process, arranged in an antero-posteriorly ascending manner which forms a curtain like separation in the centre of each half of the rosette (1-32 lamellae of one half, Fig. 38E).

The floor of the olfactory chamber is made up of palato-vomer-lateral ethmoidal complex and gets anteriorly limited by the premaxilla (PREMAX.). The median and ventro-lateral part of the floor of the olfactory chamber is constructed by palatine (PAL.). Vomer (VOM.) and ventral pad of lateral ethmoid (VEN. PAD LETH.) contribute in the formation of antero-

dorsal and posterior part of the floor respectively. The ventro-lateral extremities of the chamber is bounded by the jugals (ORB. II), lacrymals (LAC.) and adnasal (ADNAS.) while posteriorly it is limited by lateral ethmoid (LETH.). The olfactory chamber is covered dorsally and dorso-laterally by nasal (NAS.) and median ethmoid (ETH.) respectively (Figs. 39A, 39B).

The ventral pad of lateral ethmoid is pierced by a broad oval canals through which passes olfactory tract and at its anterior part lies major part of the olfactory bulb. After passing through the pads of lateral ethmoid, the olfactory tracts run through the long canal present on the surface of the orbitosphenoid.

The anterior nasal opening lies in a space bounded anteriorly and ventrally by the premaxilla, posteriorly by the nasal and medially by the median ethmoid. The posterior nasal opening is situated in the space bounded anteriorly by maxilla (MAX.), posteriorly by lateral ethmoid (LETH.), laterally by lacrymal (LAC.) and ventrally by palatine (PAL.) (Figs., 39A, 39B).

After removing the median ethmoid, lateral ethmoid and frontals from the dorsal side of the head, the brain and its relation to the olfactory rosette become clearly exposed. The olfactory bulbs (OLF. BL.) are situated close to the

Table 2 : Heteropneustes fossilis (Vase-fish)

S.No.	Total Length	No. of lamellae Rosette Right	Left	Total length of the Brain	Length of Mesencephalon	Length of Telencephalon	Ecological coefficient (Through lobes of Brain) Length of Telencephalon X 100 / Length of Mesencephalon	Retinal area of both eyes	Olfactory area of both rosette	Ecological coefficient (Through area) Olfactory area X 100 / Retinal area
1.	140 mm	46	45	5.05 mm	1.93 mm	2.13 mm	107.57	14.12 mm^2	167.54 mm^2	1186.54
2.	200 mm	60	58	8.1 mm	2.3[illegible] mm	2.45 mm	106.[illegible]8	22.14 mm^2	253.44 mm^2	1134.26
3.	220 mm	62	62	8.1 mm	2.34 mm	2.45 mm	104.70	25.12 mm^2	302.72 mm^2	1205.09
4.	250 mm	64	64	8.67 mm	2.38 mm	2.56 mm	108.82	31.28 mm^2	384.38 mm^2	1228.83
5.	270 mm	64	64	8.77 mm	2.44 mm	2.69 mm	110.24	39.24 mm^2	485.90 mm^2	1238.27

postero-ventral surface of the rosette and receive the nerve fibres from the each lamella. The olfactory bulbs are anteriorly broad and become narrow posteriorly which are joined with telencephalon by thick olfactory tracts (OLF. TR., Fig. 40). The telencephalon (OLF. LO.) is better developed as compared to the optic tectum (OP. LO.). The size of brain and its lobes are found increasing successively with respect to the size of the fish (Table 2).

Ecological co-efficient:

The usual methods are employed to calculate the ecological co-efficient in fishes varying from 140 mm to 270 mm in total length. The length of brain and number of lamellae undergo considerable increase with respect to the size of the fish (Table 2). The size of mesencephalon ranges from 1.98 mm to 2.44 mm in length where as the telencephalon varies from 2.13 mm to 2.96 mm (Table 2).

The areas of both retinae and those of rosettes of both the sides are calculated by Teichmann (1954) method and is further modified by Rahmani & Khan (1981). It is found that former ranges from 14.12 mm^2 to 39.24 mm^2 and that of latter from 167.54 mm^2 to 485.90 mm^2 (Table 2). The area of both the rosettes is higher where as the retinal area is insignificant showing thereby feebly developed optic faculty. The olfactory centre in the brain also adds further weightage to the

efficiency of the olfactory faculty. H. fossilis is, therefore, be placed under "nose-fish" category where the olfactory faculty plays its significant role in the habit of the fish such as location of food and fright reactions etc. H. fossilis is a nocturnal fish and lives in dark places which supports the findings that the fish under observations needs a better developed olfactory faculty rather than retinal (optic faculty).

The route of water circulation through the olfactory chamber of H. fossilis:

The movement of nasal barble (NAS. BAR.) and pumping activity of the ventro-lateral accessory sac, synchronously with the unidirectional beating of cilia (CI., Figs., 52, 53, 55) conduct the water current through the anterior tubular nasal opening over the anterior most part of the olfactory rosette. From there the water current is directed to the central and peripheral channels of the olfactory chamber. The channels are converged posteriorly (Figs. 37 , 38D) in a narrow lamellae-less region of the olfactory rosette which is communicated by an aperture to the accessory sac, resulting the water current to the sac after crossing the entire distance of the rosette. In this course of circulation,water travels through the interlamellar spaces and each lamella is properly bathed. The compression of accessory sac causes the exit of water current from the posterior nasal opening. The

valvular arrangement of posterior nasal opening can only allow the exit of water current, demonstrating unidirectional flow of water through the olfactory chamber.

The continuous and gradual flow of water through the olfactory chamber from anterior to posterior nasal opening is a regular feature in H. fossilis but during forward movement it becomes more rapid. The slow passage of water current through the olfactory chamber maintains a regularity with opercular movements. This indicates that respiratory movements also help to transport water through the olfactory chamber.

Fig. 41. Transverse section of the one half of the rosette of H. fossilis passing through the region of initial lamellae. The curved distal end of the lamella and swellings of submucosa are visible. Magnification X 100.

BCP.	Blood capillary
CON. TI.	Connective tissue.
DE. LAM.	Distal end of the lamella
INT. LAM. SP.	Interlamellar space
MG.	Mega- or marginal goblet cell
MSA.	Mucosa
NAN. FIB.	Nonmedullated nerve fibre bundle.
PR. LAM.	Proximal end of lamella
RPH.	Raphe
SMSA.	Submucosa
SWE	Swelling

Fig. 42. Transverse section of the one half of the rosette of H. fossilis passing through the region of middle lamellae . Cell balls are arranged against the distal tips of the lamellae and distinction of sensory and indifferent epithelium is visible in each lamella. Magnification X 100.

BC.	Basal cell
BCP.	Blood capillary
C. BALL	Cell ball
DE. LAM.	Distal end of lamella
G.	Goblet cell
IND. EPI.	Indifferent epithelium
INT. LAM. SP.	Interlamellar space.
MG.	Mega - or Marginal goblet cell
MSA.	Mucosa
MU.	Mucous
NAN. FIB.	Nonmedullated nerve fibre bundle
PR. LAM.	Proximal end of lamella
SEN. EPI.	Sensory epithelium
SMSA.	Submucosa.

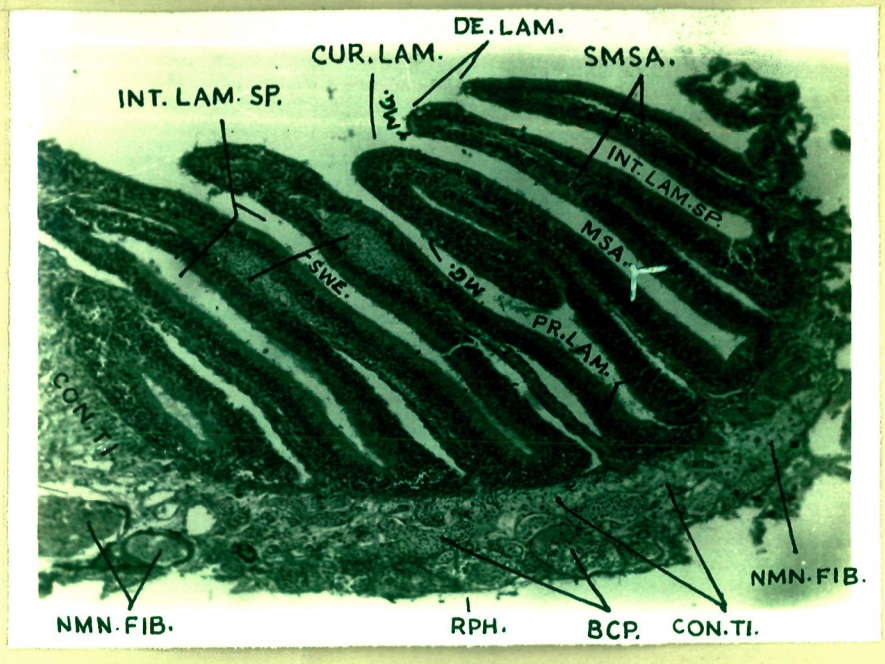


Fig. 41

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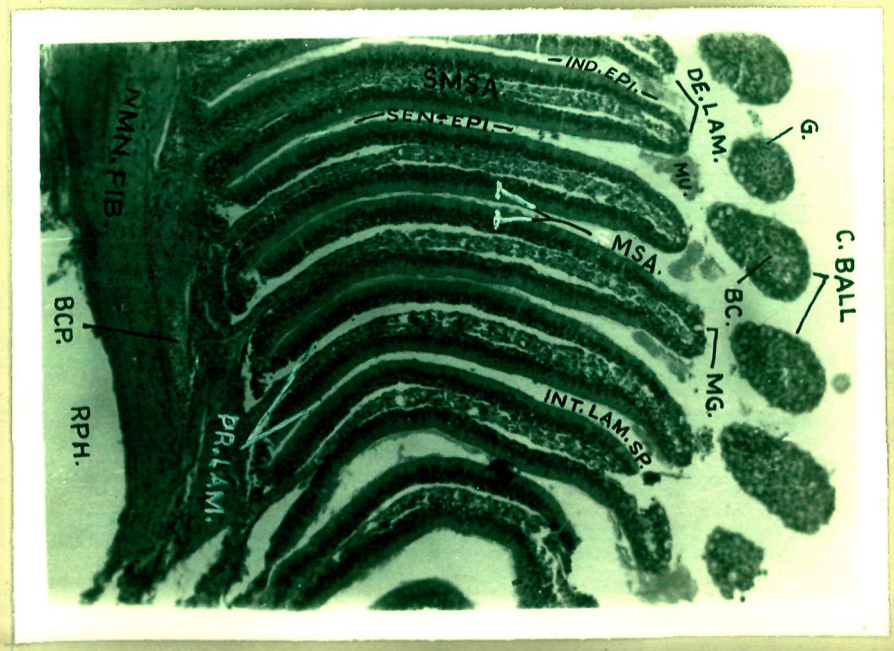

Fig. 42

42

Fig. 43. Transverse section of one half of the rosette of H. fossilis passing through the region of hinder lamellae. Enormously developed submucosa with disintegrated blood capillaries and connective tissue are visible. Magnification X 100.

BCP.	Blood capillary
C. BALL	Cell ball
DI. LAM.	Distal end of lamella
DIS. BCP	Disintegrated blood capillaries
DIS. CON. TI.	Disintegrated connective tissue
MEG.	Mieregoblet cell
MSA.	Mucosa
PIG. C.	Pigment cell
PR. LAM.	Proximal end of lamella
RPH.	Raphe
SMSA.	Submucosa.

Fig. 44A. Transverse section of one half of the rosette of H. fossilis passing through hinder lamellae and showing a stage of discharge of cell ball by the process of gradual constriction of underlying region. Magnification X 100.

BC.	Basal cell
BCP.	Blood capillary
C. BALL	Cell ball
COL. FI.	Collagen fibres
CONS.	Constriction
DET. C. BALL	Detaching cell ball
DI. LAM.	Distal end of lamella
INT. LAM. SP.	Intermalellar space
MEG.	Mieregoblet cell
MSA.	Mucosa
NCI. CU. SC.	Nonciliated cuboidal supporting cell
PR. LAM.	Proximal end of lamella
RPH.	Raphe.

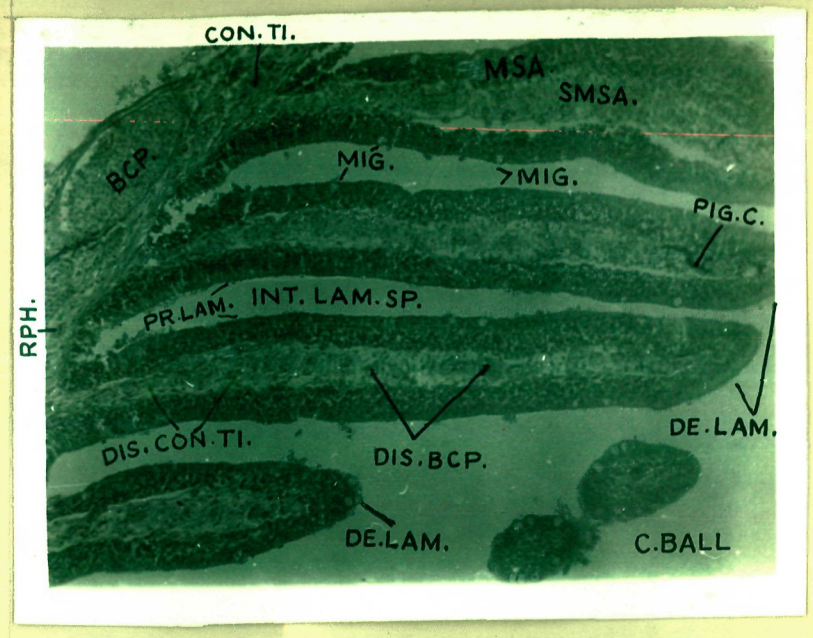

Fig. 43

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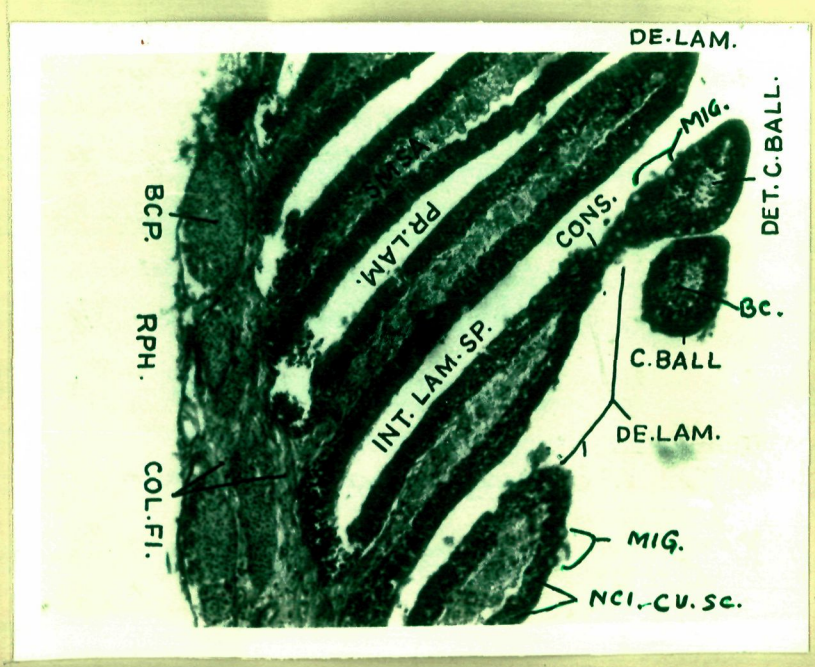

Fig. 44 (A)

44 (A)

Fig. 45A. Transverse section of one half of the rosette of H. fossilis passing through the hinder lamellae. Bud formation is visible on mother lamella and adjacent lamella is recipient one. Magnification X 100.

BM.	Basement membrane
BUD	Bud
DI. LAM.	Distal end of lamella
INT. LAM. SP.	Interlamellar space
MOT. LAM.	Mother lamella
MSA.	Mucosa
PR. LAM.	Proximal end of lamella
RECI. LAM.	Recipient lamella
RPH.	Raphe
SMSA.	Submucosa
SWE.	Swelling.

Fig. 46. Vertical section of the mother lamella of H. fossilis showing the presence of bud. Magnification X 400.

BC.	Basal cell
BCP.	Blood capillary
BUD.	Bud
CON. TI.	Connective tissue
CU. SC.	Cuboidal supporting cell
FB. C.	Fibroblast cell
MIG.	Microgoblet cell
MOT. LAM.	Mother lamella
MSA.	Mucosa
NCI.CU.EPI.	Nonciliated cuboidal epithelium
NU. CU. SC.	Nucleus of cuboidal supporting cell.

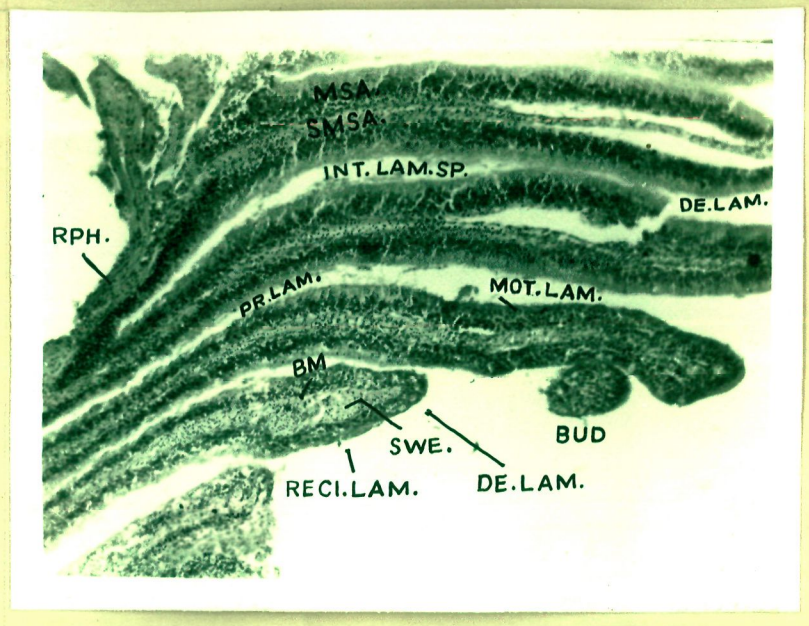

Fig. 45 (A)

45 (A)

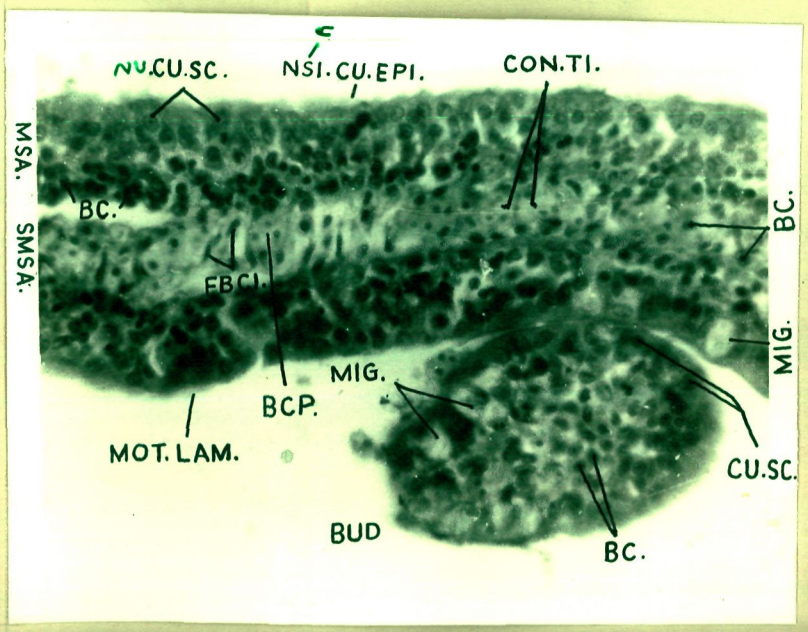

Fig. 46

46

HISTOLOGICAL OBSERVATIONS ON THE OLFACTORY ORGAN OF *HETEROPNEUSTES FOSSILIS* (BLOCH)

Olfactory epithelium forms the outlining of olfactory chamber (M. OLF. CHAM.) and is thrown into the number of lamellae which are attached on either sides of the raphe (RPH., Figs. 37, 38D, 51). It is a median antero-posterior thickening of the olfactory epithelium dividing the rosette in two clear halves. The olfactory lamellae are encapsulated by the ventro-lateral expansion of the olfactory epithelium (M. OLF. CHAM., Figs. 37,, 38D) but their dorsal and outer ends remain free, maintaining interlamellar (INT. LAM. SP., Figs, 38D, 50, 51) in between them. Each lamella is made up of central core or submucosa (SMSA.) which is an extension of the tissue underlying the ventral wall of the olfactory chamber. The central core or submucosa is lined by the cellular component of the olfactory epithelium or mucosa (MSA.) on either sides so that a lamella is vertually supported by two layers of sensory epithelium (Figs. 41, 42, 43, 46, 50). From the histological point of view all the lamellae of a rosette can be divided in three groups: initial; median and hinder. The cellular organization of these three divisions of lamellae varies greatly.

The initial lamellae are having compact cellular organization. The central core or submucosa and epithelial cellular lining are well built, giving the impression of youngest lamellae

of the rosette. They bear short, narrow structure with mucous secretary goblet cell on the extreme tip. Submucosa is comparatively narrow having rich blood and connective tissue supply (Figs. 41, 52).

The middle lamellae contain elongated body with distal end lined by indifferent epithelium (IND. EPI., Fig. 42) which is richly supplied with large flask shaped mucous secretary goblet cells. The submucosa is well built in the proximal and middle part but detached from the basement membrane in an irregular manner in the distal region of these lamellae (Figs. 42, 47, 56, 58).

Hinder ones are old and worn out set of the lamellae with enormously enlarged submucosa which has fragments of blood capillaries and loose collagen connective tissue (Figs. 43, 44A, 48A, 46, 54, 57, 59, 60). They are broad and short lined with nonciliated cuboidal epithelium (CU. EC.) and mucous secretary goblet cells (MIG.) through out their surface.

The curved (CUR. LAM., Fig. 41) and minor lamella (MIN. LAM., Figs. 49, 51) can be observed in the middle and initial lamellae respectively. The formation of minor lamella takes place in the proximal end of the lamella, forming its minor offshoot which remains attached with it. The curving is noticed in the distal end of the initial lamella where the whole of distal tip becomes curved in the form of 'U' shaped structure.

Fig. 453. The bud is showing detachment from the mother lamella and gradually elongating to join distal end of recipient lamella. This cause immediate growth to the recipient lamella. Arrow indicate the point of union of bud and recipient lamella. Magnification X 100.

BUD.	Bud
MOT. LAM.	Mother lamella
RECI. LAM.	Recipient lamella
RPH.	Raphe.

Fig. 448. The distal end of lamella discharing "cell ball" by gradual constriction of underlying region. Magnification X 100.

C. BALL.	Cell ball
CONS.	Constriction
DE. LAM.	Distal end of lamella
RPH.	Raphe.

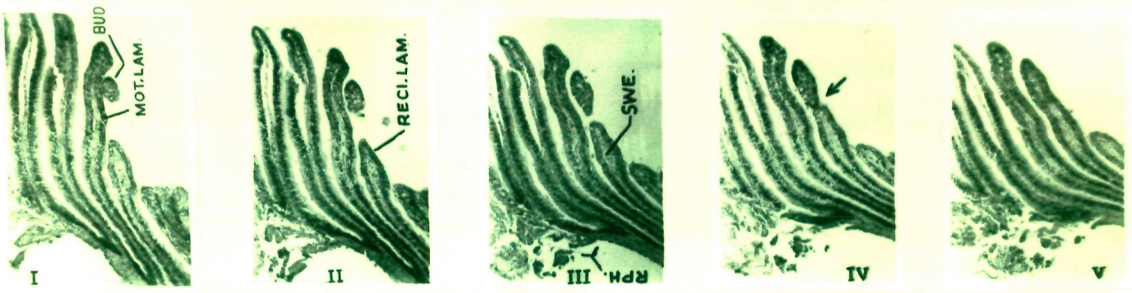

Fig. 45 (B). Bud is showing detachment from the mother lamella and gradually elongating to join distal end of recipient lamella.

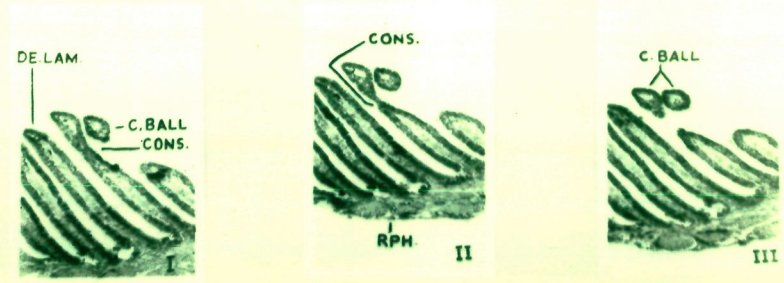

Fig. 44 (B). The distal end of lamella discharging "cell-ball" by gradual construction of underlying region.

The distal tips of the middle and hinder lamellae undergoes process of discharging their lamellar contents in the form of "cell balls" (C. BALL), containing all the contents of the olfactory epithelium (Figs. 42, 43, 44A, 47). They get discharged from the distal tips by gradual constriction (CONS., Figs. 44A, 44B, I, II, III) of the underlying region of the lamella. The "cell balls" are arranged against the distal end of the lamellae in a regular manner, showing their gradual disintegration (Figs. 42, 43, 44A, 47). This may probably be assumed that they might be supplying their contents as nutrients to the other part of the olfactory rosette (Figs. 44A, 44B, I, II, III).

The bud formation is observed in the hinder lamella which originate from the lateral surface of the distal end (Fig. 45A). This bud contains living contents of the olfactory epithelium (Figs. 46, 48) showing gradual attachment on the adjacent lamella after being detached from the mother lamella (MOT. LAM.). In this process the recipient lamella (RECI. LAM.) and the bud (BUD) elongate gradually to join each other and ultimately the latter becomes fixed on the former. This causes immediate enlargement of the recipient lamella with the result of the addition of the content of olfactory epithelium in the form of the bud (Figs. 45A, 45B, I, II, III, IV, V, 46, 48).

The submucosa swells abnormally in initial and recipient lamellae which are in the process of curving and attachment with

bud respectively (Figs. 41, 45A, 45B). This may be due to the accumulation of basal cells connective tissue, blood capillaries and other epithelial contents (Fig. 57) required for elongation of lamella for attachment with the bud or curving (CBR., LAM., Fig. 41).

On the basis of the distribution of supporting and sensory cells, the lamella of H. fossilis can be divided in following zones:

Proximal zone: Extends on either sides of raphe upto the middle region of the olfactory rosette. The anterior and middle lamellae of this region have columnar ciliated epithelium (CI. SC.) with rich supply of receptor cells (SR.). This region is devoid of mucous secretary goblet cells (Figs. 50, 52, 53, 55).

Distal zone: The distal zone of the lamella is composed of non-ciliated columnar epithelium (NCI. SC.). This zone is nonciliated but mucous secretary goblet cells (MG.) are richly present. The central core of this region is supplied with pigment cells (Figs. 47, 56, 58).

The hinder lamellae are lined with nonciliated cuboidal and mucous secretary epithelium irrespective of the distinction in the distal and proximal zones. The receptor cells are distributed upto the middle of each hinder lamella, although they are less in number (Figs. 43, 46, 48, 54, 57, 59, 60).

Fig. 47. The distal end of lamella and cell ball in H. fossilia in vertical section. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
C. BALL	Cell ball
DE. LAM.	Distal end of lamella
G.	Goblet cell
MG.	Mega- or marginal goblet cell
MU.	Mucous
NCI. SC.	Nonciliated supporting cell
SMSA.	Submucosa.

Fig. 48. Cross section of rosette of H. fossilia showing the elongation of bud and distal end of recipient lamella for joining each other. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
CU. SC.	Cuboidal supporting cell
CON. TI.	Connective tissue
ELO. BUD	Elongation of bud
GR. MIG.	Grouping of microgoblet cell
MIG.	Microgoblet cell
MOT. LAM.	Mother lamella
MSA.	Mucosa
MU.	Mucous
RECI. LAM.	Recipient lamella
SMSA.	Submucosa

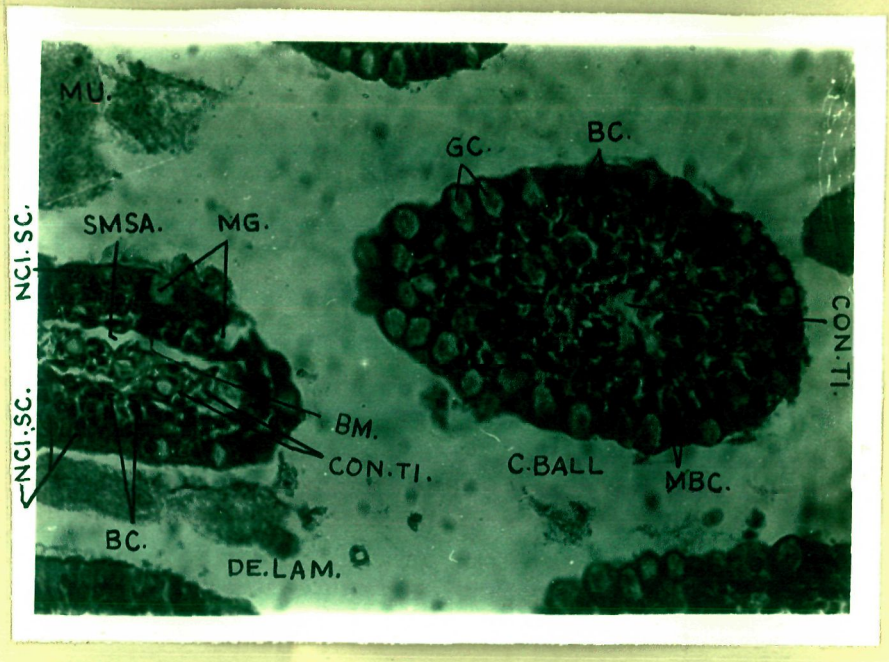
MU.
GC.
BC.
SMSA.
MG.
NCI. SC.
CON. TI.
NCI. SC.
BM.
CON. TI.
C. BALL
MBC.
BC.
DE. LAM.

Fig. 47

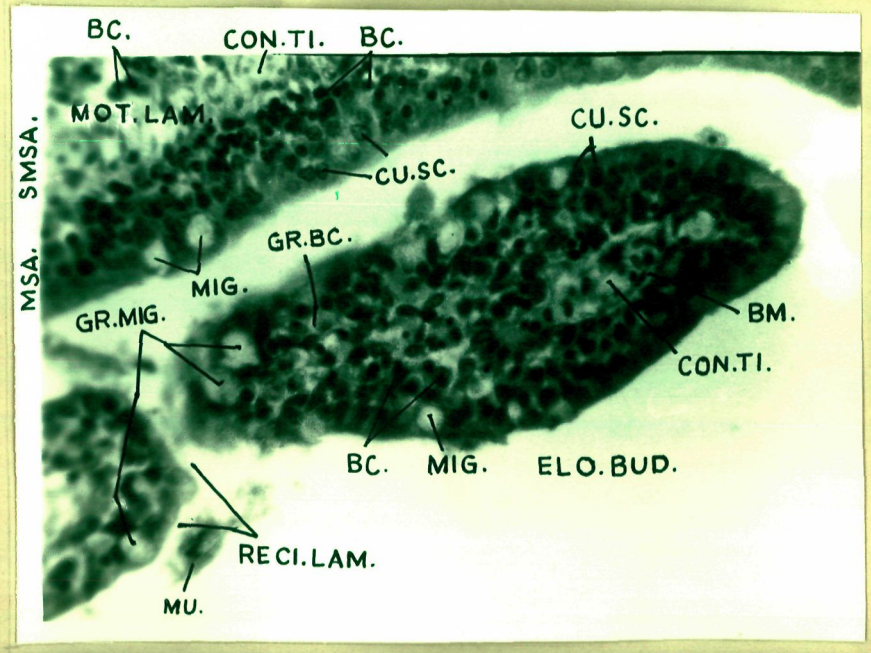
BC.
CON. TI.
BC.
MOT. LAM.
CU. SC.
SMSA.
CU. SC.
GR. BC.
MSA.
MIG.
GR. MIG.
BM.
CON. TI.
BC.
MIG.
ELO. BUD.
RECI. LAM.
MU.

Fig. 48

Fig. 49. Horizontal section of one half of the rosette of H. fossilis showing minor lamella where submucosa send its offshoots. Magnification X 100.

COL. FIB.	Collagen fibre bundle
BL. SI.	Blood sinus
INT.LAM.SP.	Interlamellar space
MIN. LAM.	Minor lamella
NMN. FIB.	Nonmedullated nerve fibre bundle
PR. LAM.	Proximal end of lamella
RPH.	Raphe.

Fig. 50. Horisontal section of rosette of H. fossilis passing through the raphe. Blood sinus with blood cells and the attachment of lamellae on its both sides visible. Magnification X 400.

BC.	Basal cell
BL. SI.	Blood sinus
BM.	Basement membrane
CON. TI.	Connective tissue
FB. C.	Fibroblast cell
FI. OL.	Folium olfactorium
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
MSA.	Mucosa
RPH.	Raphe
SG. Z.	Supporting zone
SMSA.	Submucosa.

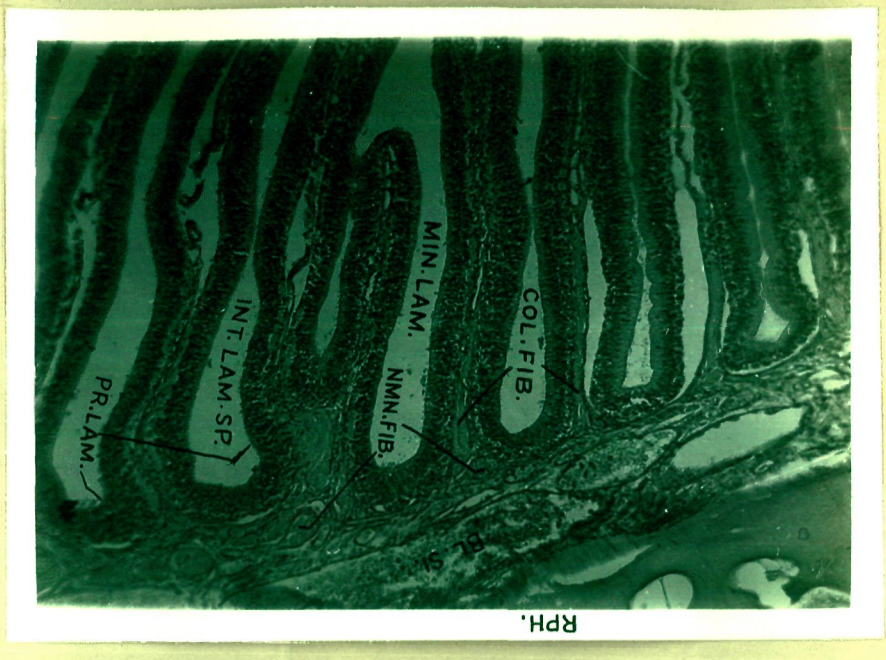

Fig. 49

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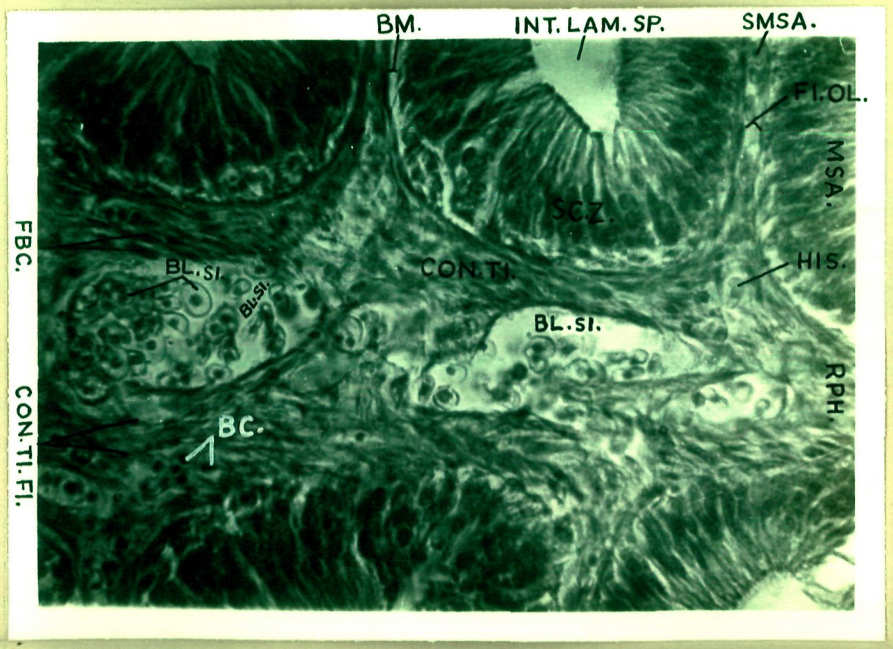

Fig. 50

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The following cell types may be identified in the olfactory epithelium of H. fossilis: supporting or sustenticular cells; receptor cells; goblet cells and basal cells. The cellular components and their nuclei are arranged in the series from inner (or basal) to outer (or peripheral) margins in following manner. The inner most position next to basement membrane (BM.) is occupied by the basal cells (BC.) having rounded or irregular nucleus. These are followed by the nuclei of spindle shaped receptor cells (SR.) and then nuclei of supporting cells. Peripheral or outer zone is filled with the distal end of the supporting cells and dendrites of the receptor cells. The goblet cells are confined in the hinder lamellae (MG., Figs. 43, 46, 48, 54, 60) or in the distal end of all the lamellae intermingled with the supporting cells (MG., Figs. 47, 56, 58).

The supporting cells:

They are columnar and cuboidal, arranged perpendicular to the central core of the lamella and contribute in the formation of greater bulk of the olfactory epithelium. These cells can be distinguished in the following types: ciliated supporting cells; nonciliated supporting cells and transitionary supporting cells.

Ciliated supporting cells (CI. SC.) are tall and richly ciliated. They are confined in the proximal and middle region

of the initial and middle lamellae. The arrangement of these cells in the olfactory epithelium is very compact and no intercellular spaces can be seen among them. The columnar cells are made of proximal or inner limb and distal or outer limb (DE. CI. SC.). The latter is broad and elongated extending upto the peripheral surface of the lamella while the former is short inconspicuous and extends upto the basement membrane. The cytoplasm of these cells frequently shows granulated appearance and granules tend to become concentrated at the distal tip. The distal end of ciliated supporting cells bear cilia (CI., Figs. 52, 53, 55) which project into the interlamellar spaces. The spherical or oval nucleus of the ciliated supporting cell lies in the proximal part of inner limb. A centrally situated nucleolus is clearly visible and chromatin material is evenly distributed in karyoplasm. The nucleus of ciliated supporting cells takes sharp stain of haematoxylin (Figs. 52, 53, 55).

Nonciliated supporting cells (NCI. SC.) are confined in the distal regions of the initial and middle lamellae but the epithelium of hinder ones is mainly made up of these cells. They are short columnar and nonciliated provided with oval nucleus (NU. NCI. SC.). The distal or outer limb (DE. NCI. SC.) is short, broad and terminates in the peripheral surface of the lamella by an expanded tip. The proximal or inner limb is inconspicuous but distal or outer end is

Fig. 51. Horizontal section of rosette of H. fossilis showing both halves and lamellar attachment on the either side of the raphe Magnification X 50.

CON. TI.	Connective Tissue
DI. LAM.	Distal end of lamella
INT. LAM. SP.	Interlamellar space
LAM.	Lamella
MIN. LAM.	Minor lamella
PR. LAM.	Proximal end of lamella
RPH.	Raphe
W. OLF. CHAM.	Wall of olfactory chamber

Fig. 52. Vertical section of initial lamellae of H. fossilis passing through sensory and ciliated supporting zone. Magnification X 400.

BC.	Basal cell
CI.	Cilia
CI SC.	Ciliated supporting cell.
COL. FIB.	Collagen fibre bundle
DN. SR.	Dendrite of spindle shaped receptor cell
FI. OL.	Fellium olfactorium
INT. LAM. SP.	Interlamellar space
NU. SR.	Nucleus of spindle shaped receptor cell
SR.	Spindle shaped receotpr cell.

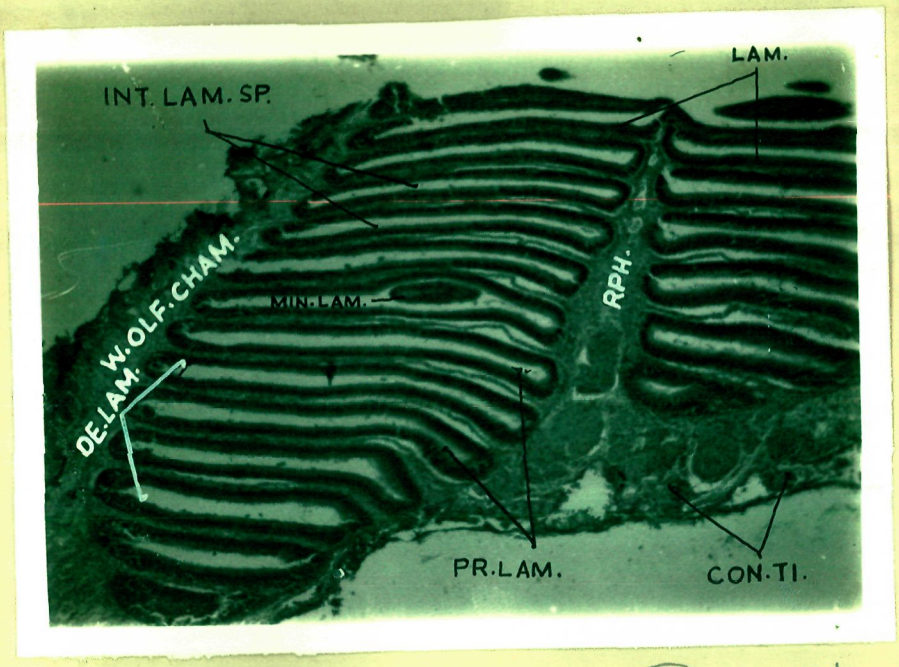
INT. LAM. SP.
LAM.
W. OLF. CHAM.
DE. LAM.
MIN. LAM.
RPH.
PR. LAM.
CON. TI.

Fig. 51

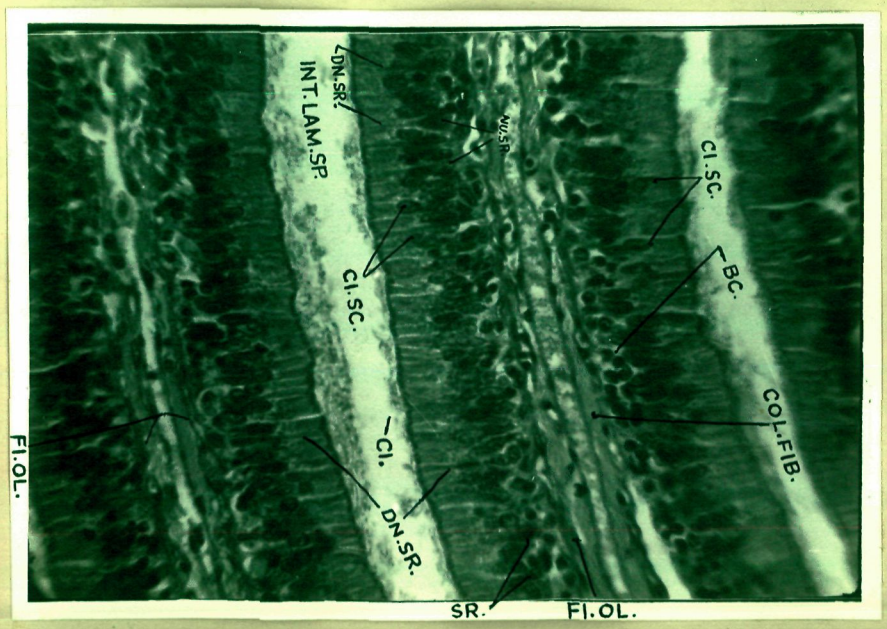
DN. SR.
INT. LAM. SP.
MD. SR.
CI. SC.
CI. SC.
BC.
COL. FIB.
FI. OL.
CI.
DN. SR.
SR.
FI. OL.

Fig. 52

prominent and broad. The nucleus lies some where in the proximal or inner side of the cell. The cytoplasm of the limbs is uniformly granulated. The nuclei of these cells lie at different levels of the epithelium with clear nucleolus and a uniform distribution of chromatin material (Figs. 47, 56, 58).

The olfactory epithelium of hinder lamellae is mainly constituted of nonciliated cuboidal supporting cells (CJ.Sc., Figs. 43, 44A, 48, 54, 57, 59, 60). They are made up of short and broad distal limb (DL. CJ. SC.) and bears darkly staining rounded nucleus (NJ. CJ. SC., Figs. 46, 48, 50, 57, 59). The cuboidal supporting cells are compactly arranged along the peripheral surface of the mucosa which provide insulation to the dendrite of spindle shaped receptor cells (Figs. 57, 59,60). The centrally placed nucleolus and chromatin material are clearly visible in the nucleus (NJ.CJ. SC.) of cuboidal supporting cells (Figs. 46, 58, 54, 57, 59, 60).

Some of the nonciliated supporting cells are positively muciperous and are denominated as transitionary supporting cells (T. SC.). The distal or outer limb of these cells become ovoid pushing the cytoplasmic and nuclear content towards the proximal or inner side. The cytoplasmic and nuclear contents remain compressed while the distal part gradually filled with the mucin forming contents (Figs. 56, 58).

The receptor cells:

The receptors cells (SR.) are confined in the proximal and middle part of all the lamellae but, however, they are highly concentrated in the middle regions. The distal regions of all the lamellae show complete absence of the receptor cells. The receptor cells are interaperesed among the ciliated columnar and nonciliated cuboidal supporting cells and their grouping in the form of olfactory bud is not observed in the olfactory epithelium of H. fossilis. The receptor cells have slender body with scanty cytoplasm surrounding the elongated and oval nucleus (NU. SR.). It takes good stain of haemotoxylin but slightly lighter than the nuclei of the surrounding supporting cells. Nucleolus and chromatin material are clearly visible in the nuclei of receptor cells. These cells are situated deep in the olfactory epithelium and send their elongated dendrite (DN. SR.) to the peripheral surface of the lamella. The dendrites can easily be identified from the distal ends of supporting cells due to their filamentous nature. The olfactory cilia (OCI.) are seen projecting out from the distal tip of dendrite of receptor cells and they are longer than the cilia of supporting cells (Figs. 52, 53, 55, 57, 59, 60). It is difficult to trace the axonal (AX. SR.) end of receptor cells but careful staining and sectioning of material reveal few of them very clear in Figs. 55, 56, 60. The axional end of all the receptor meet along the basement membrane to form folium

Fig. 53. Vertical section of the middle lamella of H. fossilis passing through the sensory and ciliated zone. The injury caused by unknown foreign body is visible. Magnification X 400.

ARE.	Areolae
BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
CI.SC.	Ciliated supporting cell
CON. TI.	Connective tissue
COL. FIB.	Collagen fibre bundle
FI. OL.	Folium olfactorium
INJ.	Injury
NAN. FI.	Nonmedulated nerve fibre
RPH.	Raphe
SR.	Spindle shaped receptor cell.

Fig. 54. Vertical section of the hinder lamella of H. fossilis. Enormously developed submucosa and disintegrated blood capillaries and connective tissue are visible. Magnification X 400.

BC.	Basal cell
BCP.	Blood capillary
BM.	Basement membrane
CONTB.	Connective tissue
CON. TI. FI.	Connective tissue fibre
FB. C.	Fibroblast cell
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
MIG.	Microgoblet cell
NCI. CU. SC.	Nonciliated cuboidal supporting cell.

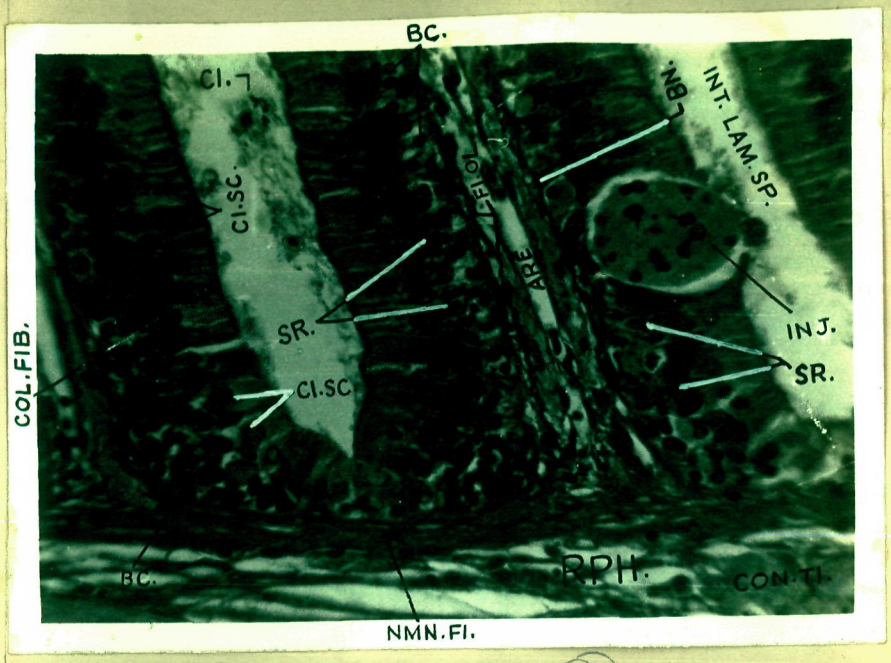

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Fig. 53

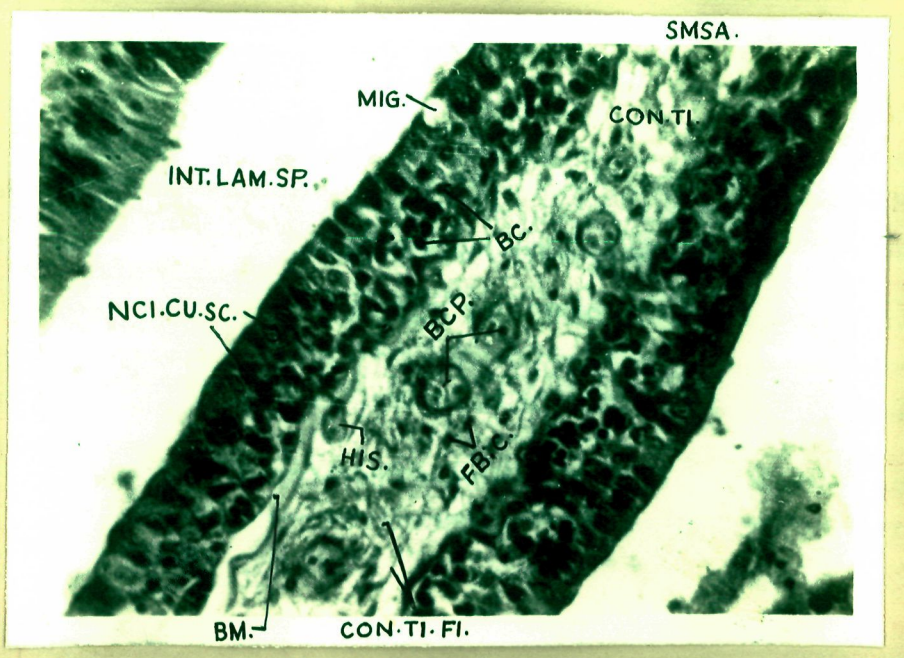

Fig. 54

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Fig. 55. Transverse section of middle lamella of H. fossilis passing through sensory and ciliated zone. Arrows indicate the pathways of dendrites and axon. Magnification X 1000.

AX. SR.	Axon of spindle shaped receptor cell
BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
COL. FIB.	Collagen fibre bundle
DE. CI. SC.	Distal limb of ciliated supporting cell
DN. SR.	Dendrite of spindle shaped supporting cell
FI. OL.	Folium olfactorium
INT. LAM. SP.	Interlamellar space
MSA	Mucosa
NU. CI. SC.	Nucleus of ciliated supporting cell
NU. SR.	Nucleus of spindle shaped receptor cell
SMSA.	Submucosa.

Fig. 56. Transverse section of middle lamella of H. fossilis passing through distal end which is lined by nonciliated supporting cells and marginal goblet cells. Epithelium is non-sensory. Magnification X 1000.

BC.	Basal cell
BM.	Basement membrane
CON. TI.	Connective tissue
DE. NCI. SC.	Distal limb of nonciliated supporting cell
FB.C.	Fibroblast cell
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
MG. TH.	Theca of marginal goblet cell
MU.	Mucous
NCI. SC.	Nonciliated supporting cell
NU. NCI. SC.	Nucleus of nonciliated supporting cell
SMSA.	Submucosa
T. SC.	Transitionary supporting cell.

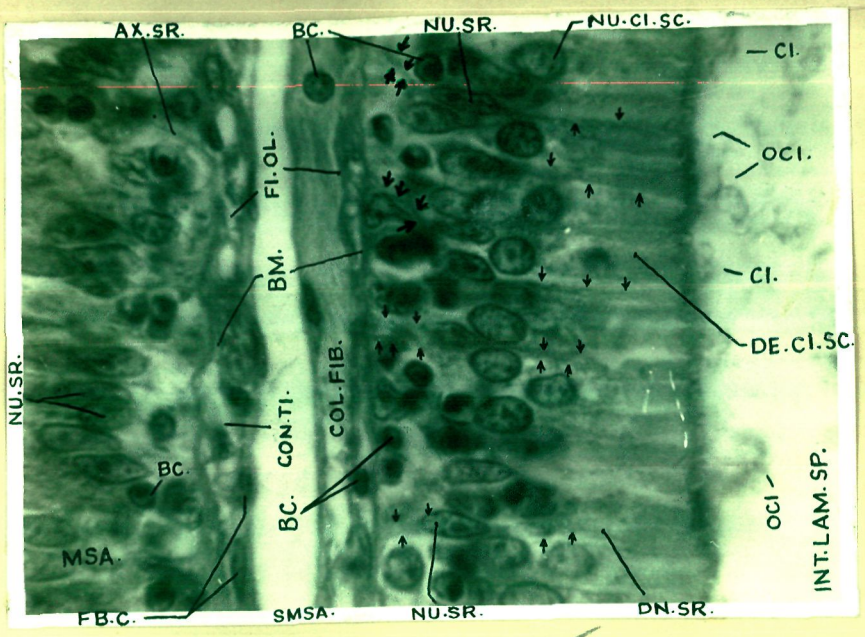

Fig. 55

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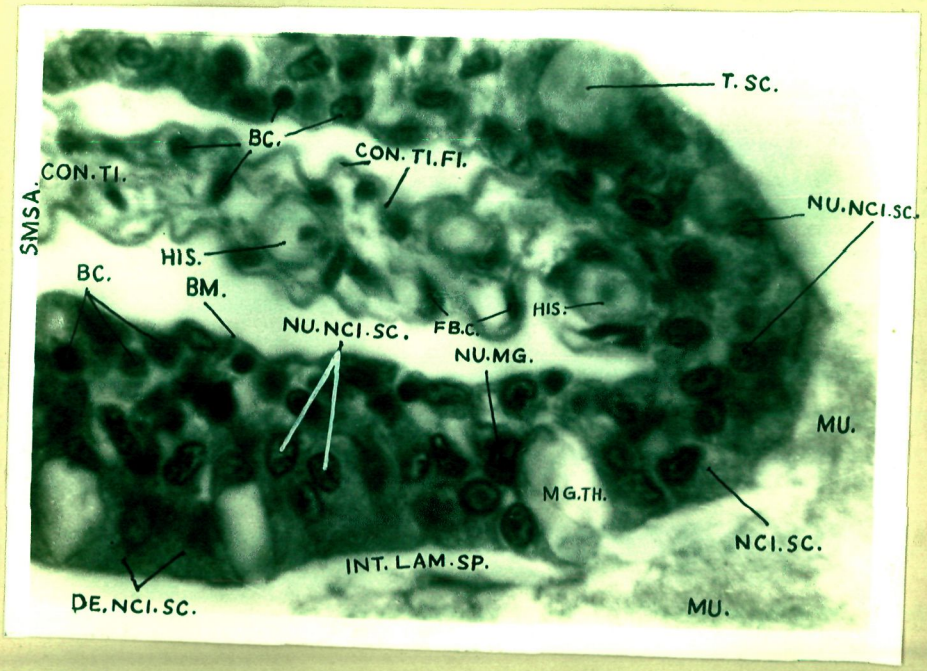

Fig. 56

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olfactorium (FO. OL.) which ultimately join nonmedullated nerve fibres (NON. FI.) passing through the raphe (Figs. 53, 61, 62).

The goblet cells:

The mucous secretary goblet cells are confined in the distal region of the initial and middle lamellae (MG., Figs. 41, 47, 56, 58) but can be encountered any where in hinder ones (MIG., Figs., 43, 46, 48, 54, 60). The proximal and middle regions of initial and middle lamellae are devoid of the mucous secretary goblet cells. A fully developed goblet cell bears an apical end filled with pale droplets mucegin and slender basal end containing compressed nucleus and small amount of the deeply staining cytoplasm. The apical part of these cells has an expanded cup which is called theca filled with secretary droplet. It becomes empty after discharging the mucous contents in the interlamellar spaces. The proximal or inner limb is stem like extending upto the basement membrane. It is hard to observe the presence of nucleolus and chromatin material in nucleus due to high degree of compression.

The goblet cells can be identified as: megagoblet cells (MG.) and microgoblet cells (MIG.) in the olfactory epithelium of H. fossilis.

The former are larger and flask shaped which are formed by the transmission of the nonciliated columnar supporting cells. The nuclear and cytoplasmic contents are pushed in the form of triangular darkly stained mass (NU. MG.) situated proximally in the cell body. They generally lie on the peripheral margin of lamella either filled with mucous or empty theca (TH. MG.) after its dischargement (Figs. 47, 56, 58).

The microgoblet cells in H. fossilia are transformed from the cuboidal supporting cells of hinder lamellae. They are present on the peripheral or outer surface of the olfactory epithelium and generally bears an outwardly projected beak (BEA.) like structure. They are having nearly oval theca (TH. MIG., Figs, 46, 48, 60) and compressed nuclear body (NU. MIG., Fig. 60). They are frequently seen in the hinder lamellae and discharged part of the lamellar contents (cell ball and bud, C. BALL AND BUD, Figs. 44, 46, 48).

The basal cells:

They are rounded with irregular branching processes. Each cell has rounded, irregular and darkly staining nucleus with faintly visible and chromatin material. The cytoplasm forms a thin border around the nucleus. The basal cells (BC.) are sparse and scanty in the proximal and middle regions of the initial and middle lamellae and are arranged in a single

Fig. 57. Transverse section of hinder lamella of H. fossilia where swelling in submucosa is visible and lined by the nonciliated cuboidal supporting cells. Arrows indicate the pathways of dendrites. One dendrite is seen projecting beyond the surface of lamella. Magnification X 1000.

BC.	Basal cell
CON. TI.	Connective tissue
DE. CU. SC.	Distal limb of cuboidal supporting cell
DN. SR.	Dendrite of spindle shaped receptor cell
FB.C.	Fibroblast cell
INT. LAM. SP.	Interlamellar space
NU. CU. SC.	Nucleus of cuboidal supporting cell
NU. SR.	Nucleus of spindle shaped receptor cell
SMSA.	Submucosa
SR.	Spindle shaped receptor cell
SWE.	Swelling.

Fig. 58. Transverse section of middle lamella of H. fossilia passing through the nonsensory, nonciliated and mucous secretory zone. Goblet cells and transitionary supporting cells are visible. Magnification X 1000.

BM.	Basement membrane
INT. LAM. SP.	Interlamellar space
MG.	Marginal goblet cell
NCI. SC.	Nonciliated supporting cell
NU. SC.	Nucleus of supporting cell
NU. MG.	Nucleus of marginal goblet cell
TH. MG.	Theca of marginal goblet cell
T. SC.	Transitionary supporting cell
SMSA.	Submucosa.

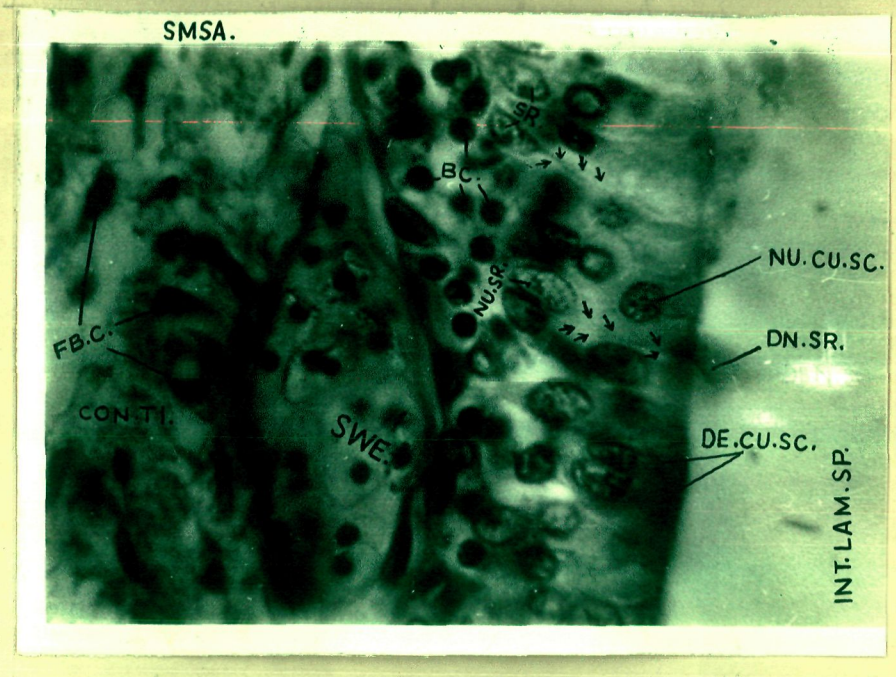

Fig. 57

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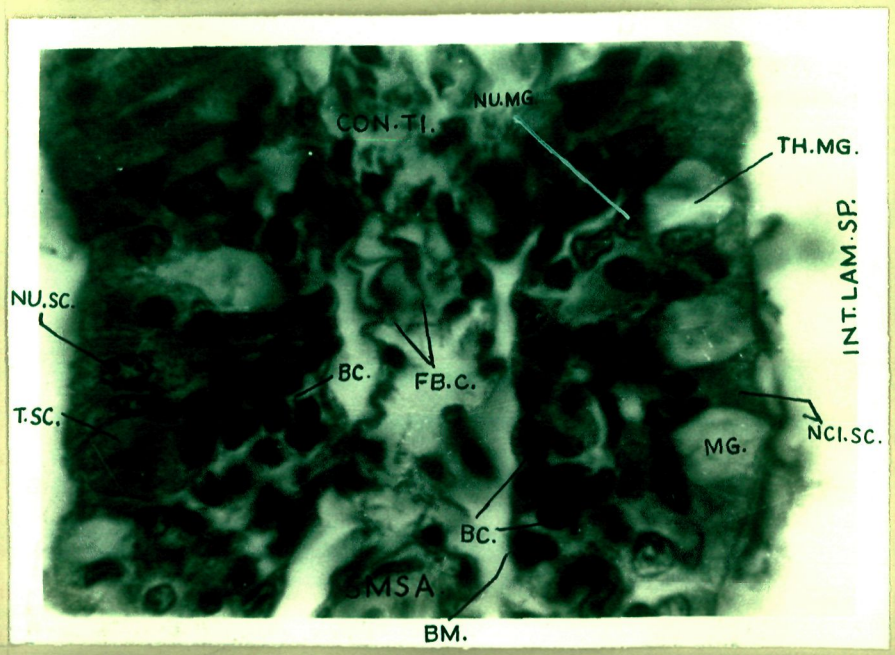

Fig. 58

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Fig. 59. Transverse section of hinder lamella of H. fossilis showing distribution of receptor cells and branched pigment cell. Arrows indicate the pathways of dendrites and axon. Magnification X 1000.

AX. SR.	Axon of spindle shaped receptor cell
BC.	Basal Cell
BR. PIG. C.	Branched pigment cell
CON. TI. FI.	Connective tissue fibre
CU. SC.	Cuboidal supporting cell
DN. SR.	Dendrite of spindle shaped receptor cell
FB. C.	Fibroblast cell
FI. OL.	Folium olfactorium
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
NU. CU. SC.	Nucleus of cuboidal supporting cell
NU.SR.	Nucleus of spindle shaped receptor cell
SMSA.	Submucosa
SR.	Spindle shaped receptor cell.

Fig. 60. Transverse section of hinder lamella of H. fossilis showing the presence of beaked goblet cells and spindle shaped receptor cells. Arrows indicate the pathways of Dendrites and axon. Magnification X 1000.

BC.	Basal cell
BEA. MIG.	Beaked microgoblet cell
BM.	Basement membrane
CON. TI.	Connective tissue
DE. CU. SC.	Distal limb of cuboidal supporting cell
FB.C.	Fibroblast cell
FI. OL.	Folium olfactorium
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
NU. CU. SC.	Nucleus of cuboidal supporting cell
NU. MIG.	Nucleus of microgoblet cell
SR.	Spindle shaped receptor cell
SMSA.	Submucosa
TH. MIG.	Thica of microgoblet cell.

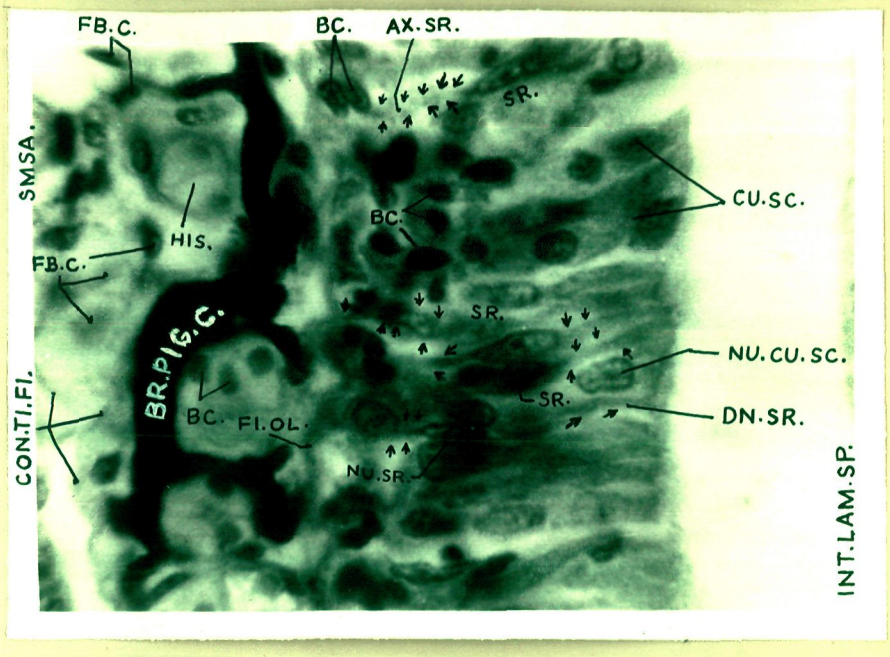

Fig. 59

61 ~~57~~ 59

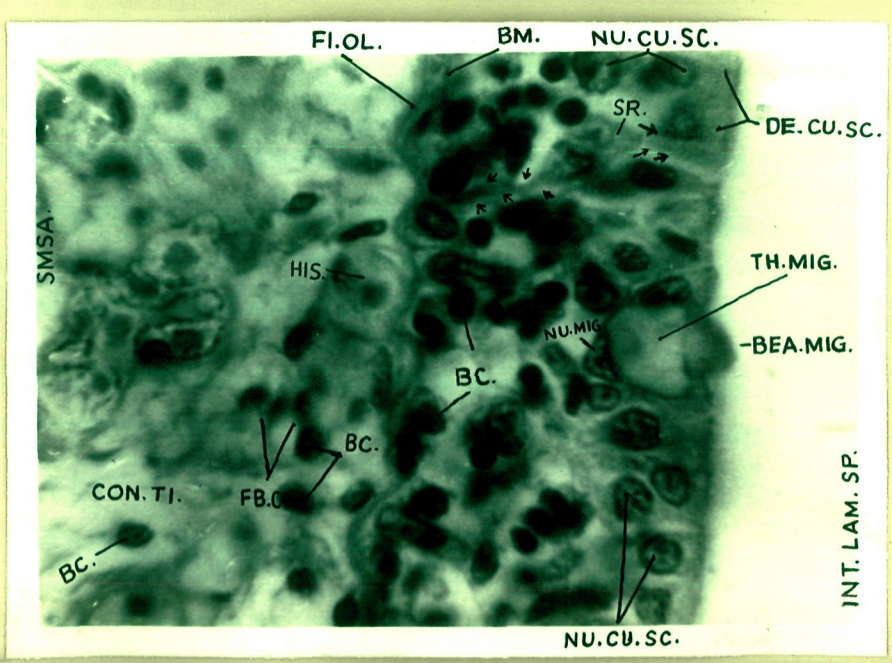

Fig. 60

62 ~~58~~ 60

Fig. 61. Transverse section of rosette of H. *fossilia* passing through the raphe. Magnification X 100.

BCP.	Blood capillary
BM.	Basement membrane
CON. TI.	Connective tissue
LAM.	Lamella
MSA.	Mucosa
NMN. FIB.	Nonmedullated nerve fibre bundle
RPH.	Raphe
SMSA.	Submucosa.

Fig. 62. Vertical section of raphe of H. *fossilia* showing nonciliated, nonsensory structure lined by columnar supporting cells. Magnification X 400.

ARE.	Areolae
BC.	Basal cell
BM.	Basement membrane
BL. C.	Blood cells
BL. SI.	Blood sinus
CON. TI. FI.	Connective tissue fibre
DS. SC.	Distal limb of supporting cell
FB. C.	Fibroblast cell
HIS.	Histocytes
NMN. FI.	Nonmedullated nerve fibre.
NU. SC.	Nucleus of supporting cell.

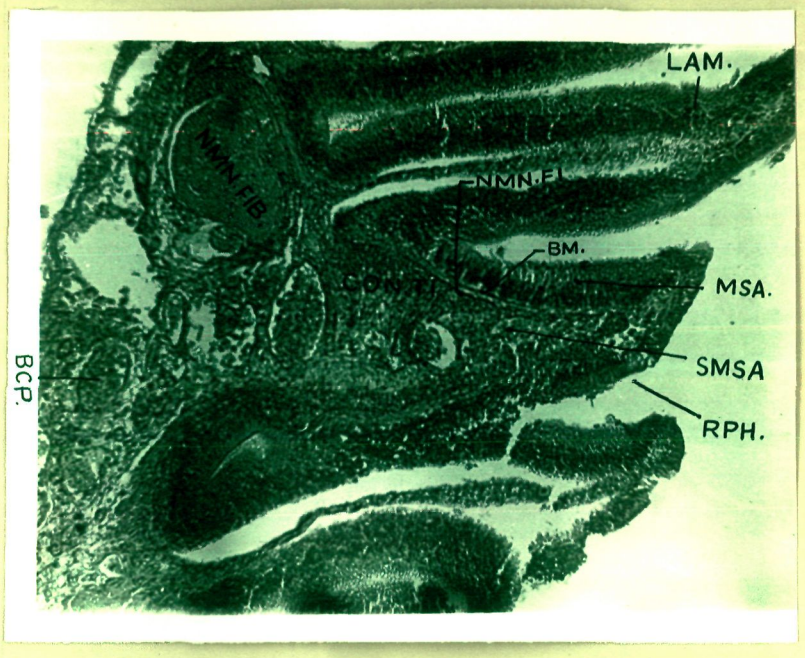

Fig. 61

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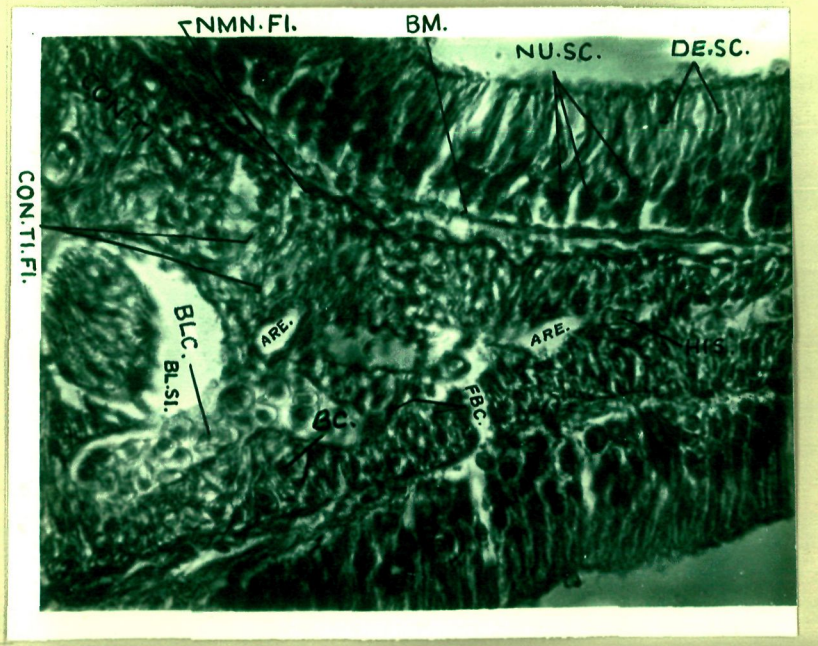


Correction PR To DE

Fig. 62

~~60~~ 62

row (Figs. 52, 53, 55). In the distal region of all lamellae and in hinder ones, these cells are irregularly arranged forming three to four rows of basal cells just above the basement membrane (Figs. 46, 47, 54, 56, 57, 59, 60). Their rich aggregation can be observed in cell ball (C. BALL, Figs. 42, 44, 47) and bud (BUD, Figs. 46, 48) formations of the lamellae. The basal cells show their specific migratory tendency towards the formations of the cell ball and bud. At the places of above formations,they are seen line up and take positions in the preparations for their eventual transformation and migration (Figs. 42, 44, 47, 48).

The central core of submucosa:

The central core or submucosa (SMSA.) is lined on either sides by a well defined basement membrane (BM.). It is filled with collagen of connective tissue and long areolae (ARE., Fig. 53) are present in between the facia of collagen connective tissue (COL. FI., Figs. 49, 52, 53, 55). In the distal region of the lamellae the areolar connective tissue is converted into dense connected tissue in which no areolae are observed. The submucosa of the hinder lamellae becomes enormously enlarged causing damage to the connective tissue fibre and blood capillaries (Figs. 43, 46, 54). The fibroblast cells (FB. C., Figs. 46, 54, 56, 57, 58, 59) are commonly observed in the central core of the distal regions of the initial and middle lamellae and in the hinder lamellae

their rich supply is noticed. The histocytes (HIS., Figs. 54, 56, 59, 60) cells and basal cells (BC., Figs. 46, 55, 56, 60) can be observed in the connected tissue. Branched pigment cell (PIG. C., Fig. 43, 59) seen in the submucosa of middle and posterior lamella which are confined in the middle and distal regions of these lamellae. The blood capillaries (BCP., Fig. 43, 46) transverse through the central core and at certain places their swellings (SWE., Figs. 41, 45, 57) can be observed. The nonmedullated (NMN. FI.) nerve fibres extend through the central core along the basement. The central core of all the lamellae is in continuation of the central core of the raphe and all the vascular, nervous and cellular supply is passed to the lamellae through it (Figs. 41, 42, 43, 49, 50).

The raphe:

The raphe (RPH.) is made up of simple columnar epithelium which lies on either sides of the well demarcated basement membrane (BM. Figs., 50, 51, 61, 62). The columnar cells bear darkly staining nucleus (NU. SC.) situated just above the basement membrane in a uniform level. The elongated distal or outer limb (DL. SC.) of these cells extend upto peripheral surface of the olfactory epithelium of raphe and is nonciliated. The proximal limb is occupied by the nucleus. Cytoplasm of columnar cells is homogeneous. No other cellular

component is seen in the olfactory epithelium of raphe of H. fossilis. The central core of submucosa of the raphe is spacious and is filled with connective tissue (CONT. TI.). The nonmedullated nerve (NON. FI., Fig. 62) fibres are observed below the basement membrane which send their nervous supply to lamella. The blood capillaries and their direction of supply can be seen in the raphe of H. fossilis. The fibroblasts (FB. C.), histocytes (HIS.) and basal cells (BC.) are rarely seen in connective tissue of the raphe (Figs. 50, 62).

The accessory sac:

The accessory sac of H. fossilis is made up of non-ciliated cuboidal epithelium. The epithelial lining of the sac is wavy and shows hillock elevations (HIL. EL.) and depressions (DEP., Fig. 63). It consists of cuboidal supporting (CU. SC.) cells, rounded goblet cells (MUC.) and basal cells (BC., Fig. 64).

The cuboidal cells are situated in the periphery with darkly stained oval nucleus. They can be seen in two or three rows in elevated regions of the epithelium. The goblet cells are rounded, neckless and found embedded in the peripheral epithelial surface. They can also be observed with empty theca after discharging their mucous contents. They can also be seen in two or three rows in regions of elevations. The

Fig. 63. Cross section of ventro-lateral accessory nasal sac of H. fossilis. Magnification X 100.

BM.	Basement membrane
CON. TI. FI.	Connective tissue fibre
DPR.	Depression
HIL. EL.	Hillock elevation
LUM.	Lumen
MIG.	Microgoblet cells
NON. FIB.	Nonmedulated nerve fibre bundle.

Fig. 64. Cross section of ventro-lateral accessory nasal sac of H. fossilis. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
CON. TI. FI.	Connective tissue fibre
CU. SC.	Cuboidal supporting cell
FB. C.	Fibroblast cell
GR. BC.	Grouping of basal cell
LUM.	Lumen
MIG.	Microgoblet cell.

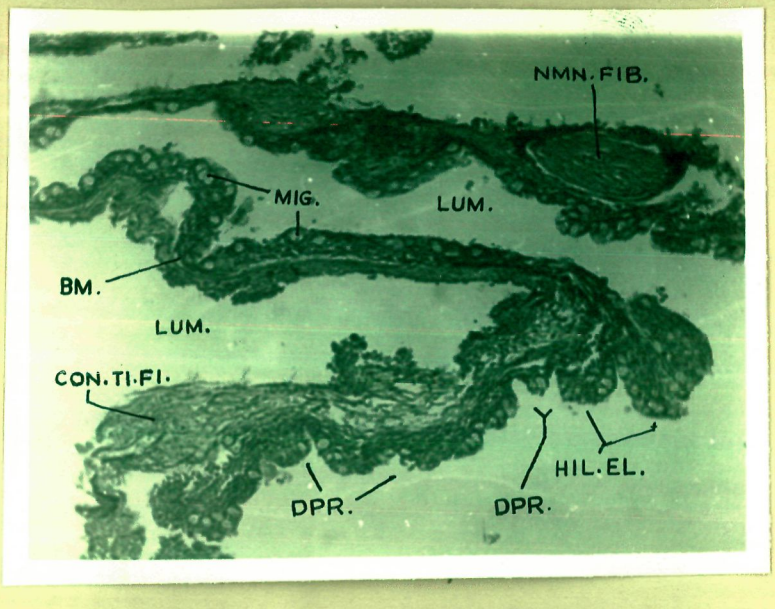


Fig. 63

63 63

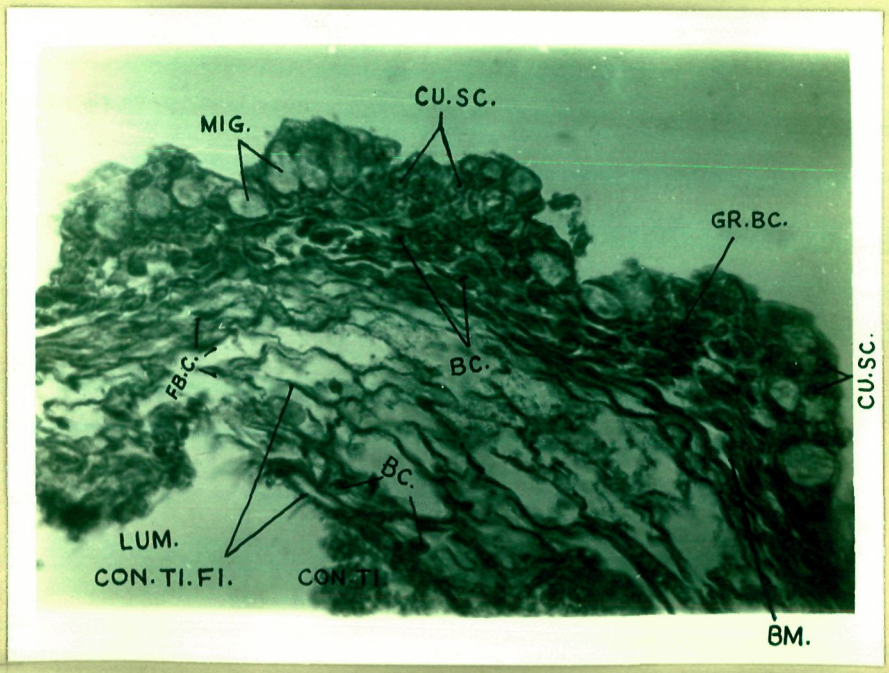


Fig. 64

64

basal cells lie in three or four rows just above the basement membrane. In the elevations, basal cells are accumulated in large number and show their migratory tendancy towards the periphery.

They wavy basement membrane lies just below the basal cells and is followed by the elastic connective tissue. The elastic fibres are loosely cemented with matrix and are also followed by the thin collagen fibres. The fibroblasts and basal cells can also be observed within the elastin and collagen fibres connective tissue. Blood capillary and non-medullated nerve fibres are present in the connective tissue of the accessory sac of H. fossilia (Fig. 64).

The number of sac layers vary with the distension of accessory sac. In a normal condition, the cuboidal epithelial and basal cells are accumulated in 9 - 11 layers. The elastin fibres and basement membrane is wavy, however, in a distended condition the accessory sac consists of 2-3 layers of basal cells. The basement membrane and elastic fibres are stracked.

ANATOMICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF NOTOPTERUS NOTOPTERUS (PALLAS)

The olfactory chambers of N. notopterus are represented by a pair of olfactory chambers (OLF. CHA.) which lie dorso-laterally on the head in front of the eye orbit (Fig. 65). They occupy a large oval areas extending from the tip of the snout to the eye orbit and are richly supplied with the chromatophores (Figs. 65, 67A). Each olfactory chamber communicates out side by a pair of nasal openings where posterior is flush with the general surface of the skin (Figs. 65, 67A, 67B). The anterior nasal opening (ANT. NAS. OP.) is rounded and thickly rimed (RIM., Fig. 67C) and lies latero-medially on the roof of skin. A forwardly directed and ventrally grooved nasal tentacle (NAS. TEN.) rests on the rim of the anterior nasal opening (Figs. 65, 67A, 67B). The posterior nasal opening (POST. NAS. OP.) is a single, oval and nonvalvular aperture lying laterally on the antero-dorsal of the eye-orbit. It lies on the posterior extremities of the nasal (NAS.) and adnasal (ADNAS.) bones (Fig. 68A). In a fish of 22 cm the anterior and the posterior nasal openings lie at a distance of 0.8 cm and demarcate the anterior and posterior extremities of the olfactory chamber (Figs. 65, 67A, 67B).

The olfactory rosette is an elongated, boat shaped structure and bearing ventral convex and dorsal concave surfaces

Fig. 65 Lateral view of the head of *N. notopterus*.

NAS. TEN. - Nasal tentacle

OLF. CHA1. - Olfactory chamber

POST. NAS. OP. - Posterior nasal opening.

Fig. 66. Dissection of the head of *N. notopterus* from lateral side to show rosette insitu.

ADNAS. H. - Adnasal half

CEN. CH. - Central channel

LING. - Linguiform process

NAS. H. - Nasal half

PER. CH. - Peripheral channel

RPH. - Raphe

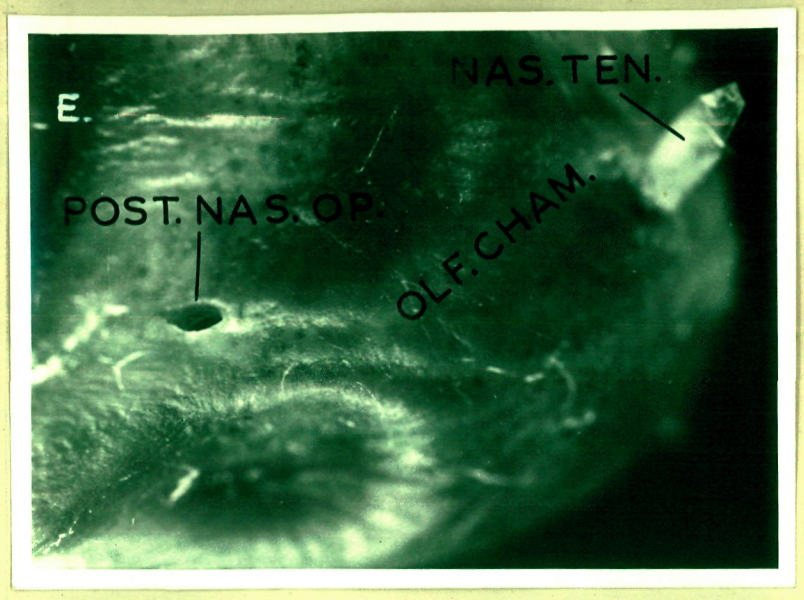

E.
NAS. TEN.
POST. NAS. OP.
OLF. CHAM.

Fig. 65

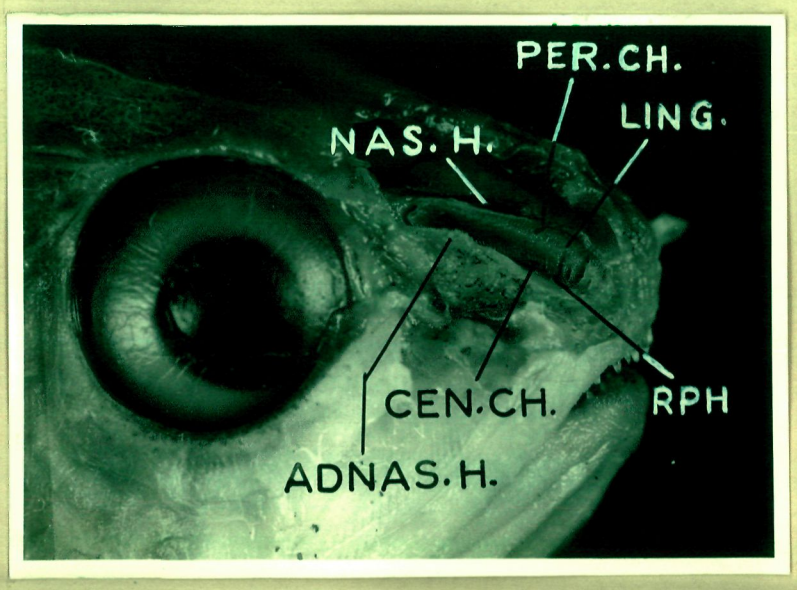

PER. CH.
LING.
NAS. H.
CEN. CH.
RPH
ADNAS. H.

Fig. 66

Fig. 67A. Diagram of the lateral view of head of N. notopterus.

Fig. 67B. Diagram of the olfactory chamber with rim, nasal tentacle and posterior nasal opening of N. notopterus.

Fig. 67C. The nasal tentacle is removed to show the position of anterior nasal opening in N. notopterus.

Fig. 67D. A set of 1 - 33 lamellae from one half of the rosette of N. notopterus.

ANT. NAS. OP.	-	Anterior nasal opening
EY.	-	Eye
NAS. TEN.	-	Nasal tentacle
OLF. CHAM.	-	Olfactory chamber
POST. NAS. OP.	-	Posterior nasal opening
RIM	-	Rim.

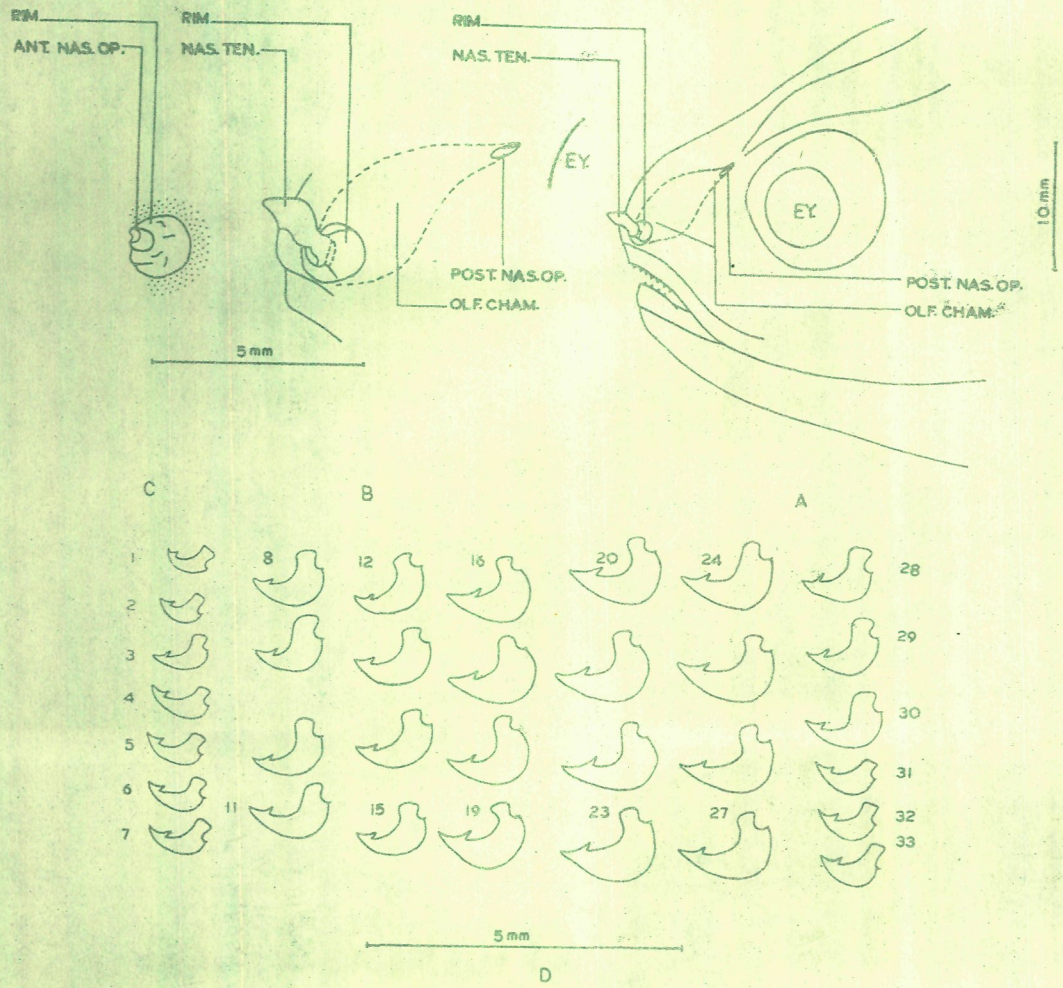
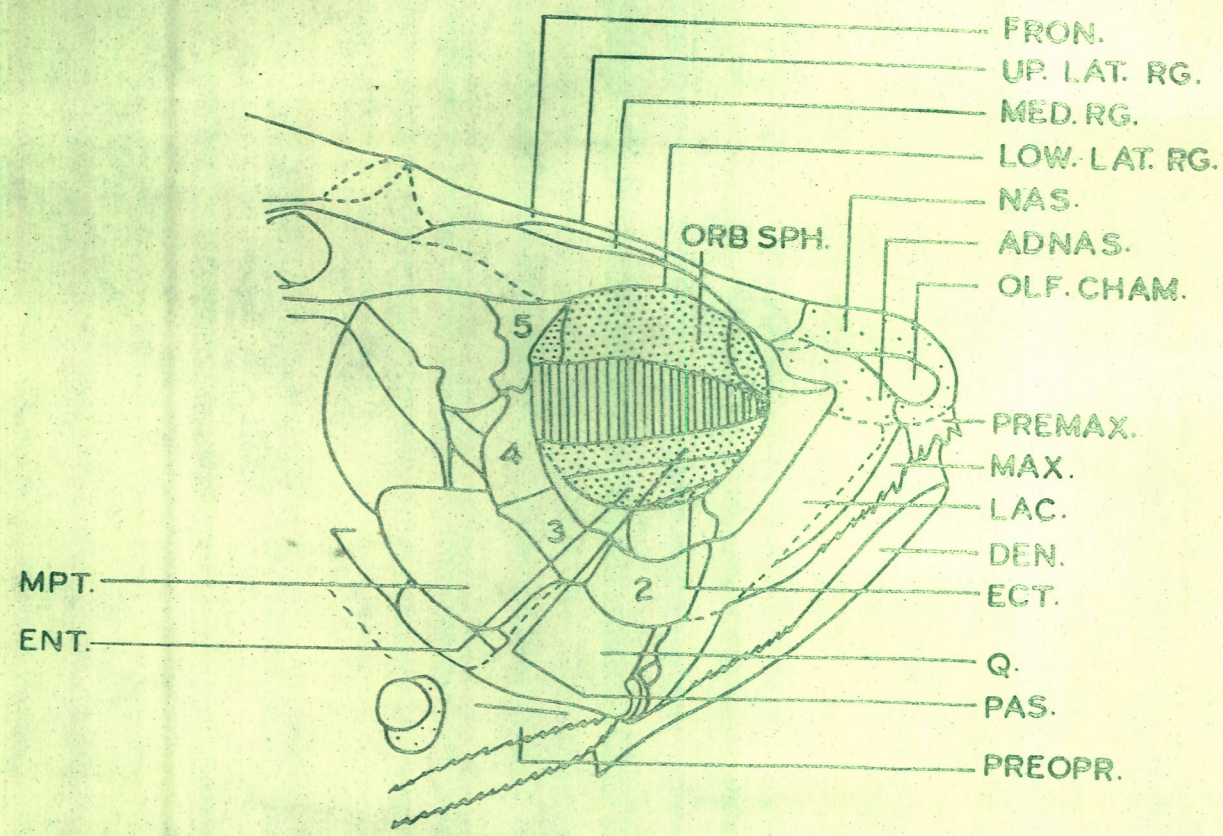

RIM
ANT. NAS. OP.
RIM
NAS. TEN.
RIM
NAS. TEN.
EY.
EY.
POST. NAS. OP.
OLF. CHAM.
POST. NAS. OP.
OLF. CHAM.
5 mm
10 mm
C
B
A
1
2
3
4
5
6
7
8
11
12
15
16
19
20
23
24
27
28
29
30
31
32
33
5 mm
D

FIG. 67.

Fig. 68A. Diagram of the lateral view of the skull of N. notopterus. (Posterior region is not drawn) 2, 3, 4, 5 circumorbitals.

Fig. 68B. Ethmoidal region after removing the adnasal, nasal and orbitals to show the floor of olfactory chamber in N. notopterus.

ADNAS.	-	Adnasal
DEN.	-	Dentary
ECT.	-	Ectopterygoid
ETH.	-	Ethmoid
FRON.	-	Frontal
LAC.	-	Lacrymal
LETH.	-	Lateral ethmoid
LOW. LAT. RG.	-	Lower lateral ridge
MAX.	-	Maxilla
MED. RG.	-	Median ridge
NAS.	-	Nasal
OLF. CHAM.	-	Olfactory chamber
OLF. FOR.	-	Olfactory foramen
ORBSPH.	-	Orbitosphenoid
PAS.	-	Parasphenoid
PREMAX.	-	Premaxilla
PRE. OP.	-	Preoperculum
Q.	-	Quadrate
UP. LAT. RG.	-	Upper lateral ridge.
ENT.	-	Entopterygoid
MPT.	-	Metapeterygoid


FRON.
UP. LAT. RG.
MED. RG.
LOW. LAT. RG.
NAS.
ADNAS.
OLF. CHAM.
ORB SPH.
PREMAX.
MAX.
LAC.
DEN.
ECT.
Q.
PAS.
PREOPR.
MPT.
ENT.
5
4
3
2
10 mm
A

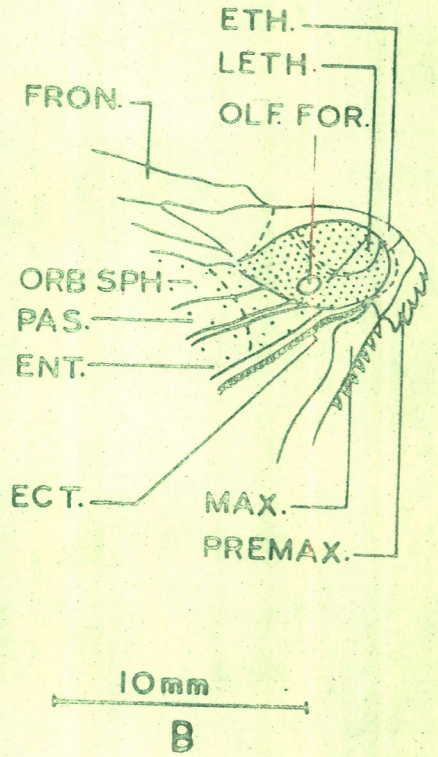

ETH.
LETH.
FRON.
OLF FOR.
ORB SPH.
PAS.
ENT.
ECT.
MAX.
PREMAX.
10 mm
B

FIG. 68.

(Figs. 66, 98). The former is pigmented (PIG.) and is covered by the fibrous epithelium but the latter is provided with free dorsal ends of the olfactory lamellae (LAM., Fig. 98). In between the two lamellae a conspicuous interlamellar space (INT. LAM. SP., Figs. 70, 71, 72, 98) is present. The rosette is made of two halves and are named as nasal and adnasal halves (NAS. H. AND ADNAS. H., Fig. 66) by virtue of their positions in relation to nasal and adnasal bones. A raphe (RAH.) runs antero-posteriorly in the centre of each rosette and lamellae (LAM.), radiate vertically on its either sides (Figs., 71, 72, 82, 98). The arrangement of the lamellae in each half of the olfactory rosette is in a manner that larger ones are present in the postero-mesial part whereas the endings are provided with smaller ones (Fig. 67D, Nos. 1-33). The anterior most lamella is smaller as compared to that of posterior most. It is, therefore, suggested that the commencement of growth has taken place from the anterior to posterior. The pigment cells (PIG. C.) are mainly confined on raphe and also on the distal region of all the lamellae (Figs. 70, 71, 72).

The olfactory lamellae (LAM.) in N. notopterus are plough shaped and bear dorsal concave and ventral convex surfaces. The latter is attached to the fibrous olfactory epithelium while former is free and forms interlamellar spaces in between the lamellae (Figs. 70, 71, 72, 98). They are provided with narrow proximal end pointed and curved distal ends. The proximal is

Fig. 69. Diagram of the dissection of the head of *N. notopterus* from dorsal side to show relationship of brain with the rosette.

CE.	- Cerebellum
EY.	- Eye
OLF. BL.	- Olfactory bulb
OLF. LO.	- Olfactory lobe
OLF. TR.	- Olfactory tract
OP. LO.	-8 Optic lobe
RE.	- Rosette.

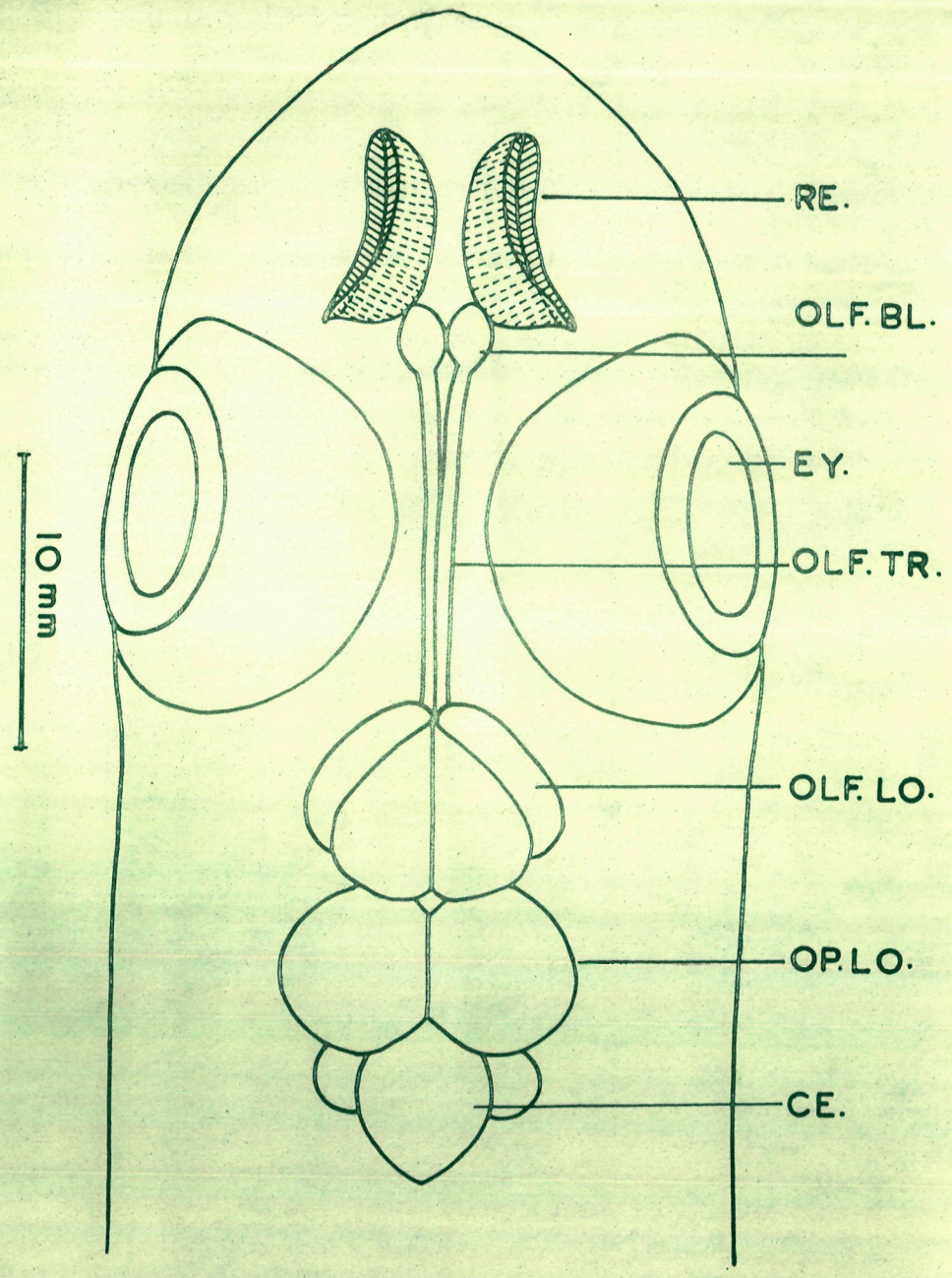


FIG. 69.

attached with the raphe while the distal end with the wall of the olfactory chamber. The mesial part of each lamella is broad and linguiform process (LING., Fig. 98) is present distally on the dorsal surfaces. The linguiform process of all the lamellae form a curtain in the peripheral region of the olfactory chamber and divide it into the central and peripheral channels (CEN. CH. AND PER. CH., Fig. 66). The water in the olfactory chamber circulates from central to the peripheral channels before its expulsion from the posterior nasal opening (1-33 lamellae of one half, Fig. 67D).

The olfactory rosette is lodged in a bowl shaped olfactory chamber in the ethmoidal region and is attached with the surrounding bony components by fibrous connective tissue. The floor of the olfactory chamber is mainly composed of grooved lateral ethmoid (L. ETH.). The ethmoidal ridge (ETH., Fig. 68B) separates the olfactory chambers of either side and contributes in the formation of one third medio-lateral part of the floor of the olfactory chamber. The nasal (NAS.) and adnasal (ADNAS.) bones contribute in the formation of the margins of olfactory chamber. The left margin of right olfactory chamber and right margin of left olfactory chamber are bounded by the nasal. The adnasal erects opposite to nasal in each olfactory chamber. Both nasal and adnasal terminate posteriorly to form the posterior nasal opening (Figs. 68A, 68B).

The lateral ethmoid terminates posteriorly into a narrow process and articulates with the orbito-sphenoid (ORB. SPH.). The olfactory bulb lies in a groove present at a point of articulation of lateral ethmoid and orbito-sphenoid. The lateral ethmoid bears a foraman (OLF. FOR., Fig. 68B) for the opthalmicus profundus nerve. The olfactory tracts run throughout the length of orbito-sphenoid and plaurosphenoid.

The olfactory chamber is anteriorly supported by the premaxilla (PREMAX.) while posteriorly by the upper and lower longitudinal ridges (UP. LAT. RG. AND LOW. LAT. RG.) of the frontal (FRON.). The parasphenoid (PAS.) and vomer lies mid-ventrally in between the two chambers. Ventro-laterally and dorso-laterally, the olfactory chambers are supported by the ectopterygo-palatine and lacrymal (LAC.) bones, respectively (Figs. 68A, 68B).

The dissection of the head from its dorsal side shows anatomical relationship of the brain to the olfactory rosette (RE.). The olfactory bulbs (OLF. BL.) are rounded and situated close to the posterior of the olfactory rosette. The paired olfactory tracts (OLF. TR.) are elongated and originate from the anterior most part of telencephalon (OLF. LO.) and terminate to the olfactory bulb. Each olfactory bulb (OLF. BL.) gives rise to a pair of the olfactory nerves (OLF. NE) extending postero-anteriorly on the ventral surface of rosette (Fig. 69).

Table 3 : Notopterus notopterus (Dye-nose fish)

S.No.	Total length	No.of lamellae Rosette Right	Rosette Left	Total length of the Brain	Length Diencephalon	Length of Telencephalon	(Ecological coefficient) (Through Lobes of Brain) Length of Telencephalon X 100 / Length of Diencephalon	Retinal area of both eyes	Olfactory area of both rosette	Ecological coefficient (Through area) Olfactory area X 100 / Retinal area
1.	344 mm	58	5[illegible]	4.[illegible] mm	2.[illegible] mm	3.16 mm	112.80	48.80 mm^2	[illegible]24.08 mm^2	1393.61
2.	[illegible]70 mm	63	62	7.[illegible]5 mm	3.16 mm	3.51 mm	111.07	52.52 mm^2	1038.26 mm^2	1976.98
3.	430 mm	66	66	[illegible]5 mm	3.51 mm	3.86 mm	10[illegible]7	156.52 mm^2	3022.40 mm^2	1930.09
4.	520 mm	60	60	11.11 mm	3.96 mm	4.32 mm	111.[illegible]1	127.16 mm^2	2550.72 mm^2	2012.90
5.	590 mm	80	80	11.3[illegible] mm	4.0[illegible] mm	4.68 mm	114.42	180.96 mm^2	3[illegible]59.30 mm^2	1978.99

Ecological co-efficient:

For calculating the ecological co-efficient usual methods are adopted. Five fishes of different sizes ranging from 244 mm to 580 mm are selected for calculating the ecological co-efficient. It is found that the length of the mesencephalon ranges from 2.89 mm to 4.09 mm and that of telencephalon from 3.26 mm to 4.68 mm. The area of two retinae and both rosettes was also measured by method suggested by Teichmann (1954) and further modified by Rahmani & Khan (1981). The former ranges from 48.80 mm^2 to 189.96 mm^2 and that of latter from 924.08 mm^2 to 3759.30 mm^2 (Table 3). By considering the parameters of length of the optic and olfactory centres of brain, N. notopterus bears much developed olfactory centre but the value of optic centre is also significant and can not be ignored. Similarly areas of both the rosettesstand quite higher but here too retinal area is also of considerable value. This indicatesthat though N. notopterus is having highly developed olfactory faculty but development of optic faculty is also of significant importance indicating "Eye-Nose" category of this fish. In N. notopterus the optic and olfactory faculties might be playing an equal and important role in recognising the food material and fright reaction etc.

The route of the circulation of water through the olfactory chamber of N. notopterus:

The action of cilia of supporting zone of the olfactory lamellae, synchronously with the opercular movements create water

current through the olfactory chamber. The nasal tentacles help in directing the water current towards the anterior nasal opening. The remarkably large and dense cilia (Cl., Figs. 70, 74, 76) of the supporting distal zone of the lamellae beat unidirectionally, directing the passage of ingoing water current from anterior to posterior nasal opening via interlamellar spaces of the rosette. During the course of water circulation the sensory zone of the rosette is irrigated properly, allowing the easy realisation of the sense of olfaction of the odorent present in water current. In addition to it, the forward movement of the fish and opening of jaws intensify the rate of water transportation through the olfactory chamber.

Fig. 70. Horizontal section of the rosette of N. notopterus passing through the supporting zone with ciliated interlamellar space, pigment cells, blood capillaries and wall of the olfactory chamber. Magnification X 100.

CI. INT. LAM. SP.	Ciliated interlamellar space
CON. TI.	Connective tissue
PIG. C.	Pigment cells
SMSA.	Submucosa
W. OLF. CHAM.	Wall of olfactory chamber

Fig. 71. Horizontal section of the rosette of N.notopterus passing through the raphe and showing sensory zone of lamellae on its (raphe) either sides pigment cells are confined to raphe. Magnification X 400.

ARE.	Areolae
BM.	Basement membrane
BR. PIG. C.	Branched pigment cell
COL. FIB.	Collagen fibrebundle
CON. TI.	Connective tissue
FI. OL.	Filum olfactorium
NCI.INT.LAM.SP.	Nonciliated interlamellar space
NCI. SC.	Nonciliated supporting cells
RPH.	Raphe
SEN. Z.	Sensory zone
SMSA.	Submucosa

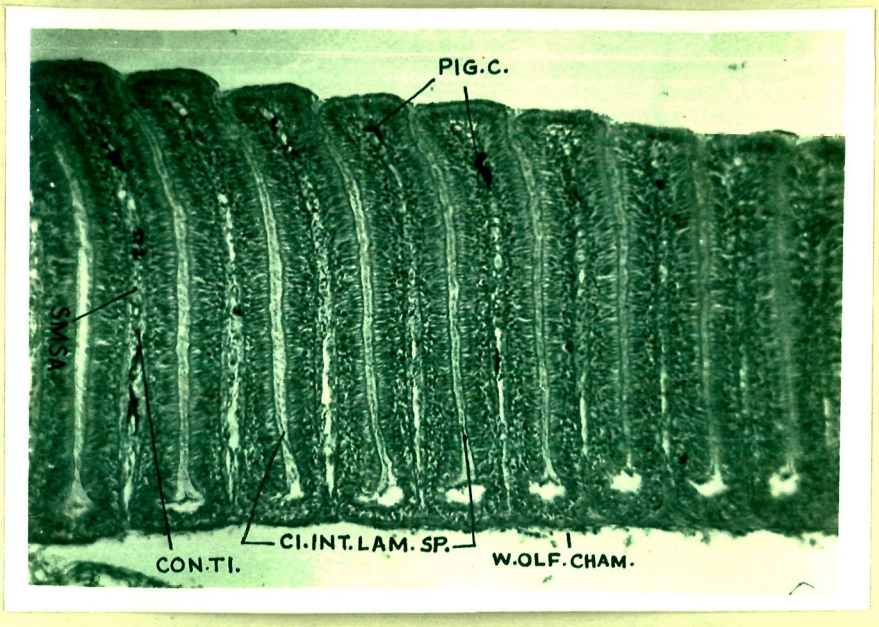


Fig. 70

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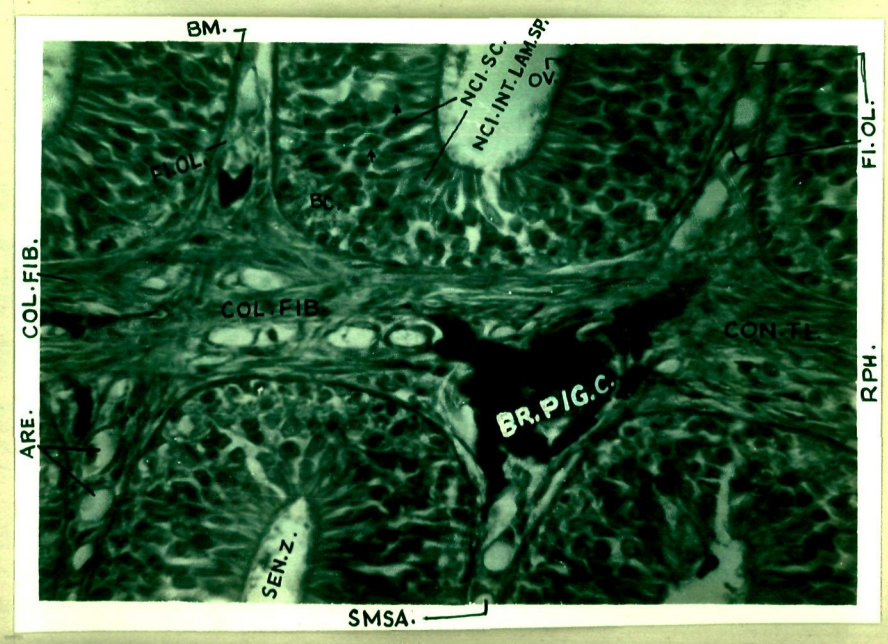

Fig. 71

71

Fig. 72. Horizontal section of N. notorterus of one complete half of the rosette. The sensory and supporting zones are clearly distinguished. Magnification X 100.

INT. LAM. SP.	Interlamellar space
LAM.	Lamella
MSA.	Mucosa
PIG. C.	Pigment cell
RPH.	Raphe
SEN. Z.	Sensory zone
SMSA.	Submucosa
SUPP. Z.	Supporting zone
W. OLF. CHAM.	Wall of olfactory chamber

Fig. 73. Transverse section of a lamella of N. notorterus. Submucosa is provided with nonmedullated nerve fibre bundles. Magnification X 1000.

BC.	Basal cell
BGR.	Basal granule
BM.	Basement membrane
CI.	Cilia
DE. CI. SC.	Distal limb of ciliated supporting cell.
FI. OL.	Filum olfactorium
GR. BC.	Group of basal cells
HIS.	Histocytes
INT. LAM. SP.	Interlamellar space
LYM.	Lymphoid cells
NON. FIB.	Nonmedulated nerve fibre bundle
NU. CI. SC.	Nucleus of ciliated supporting cells
PIG. C.	Pigment cell
PR. CI. SC.	Proximal limb of ciliated supporting cells
SMSA.	Submucosa

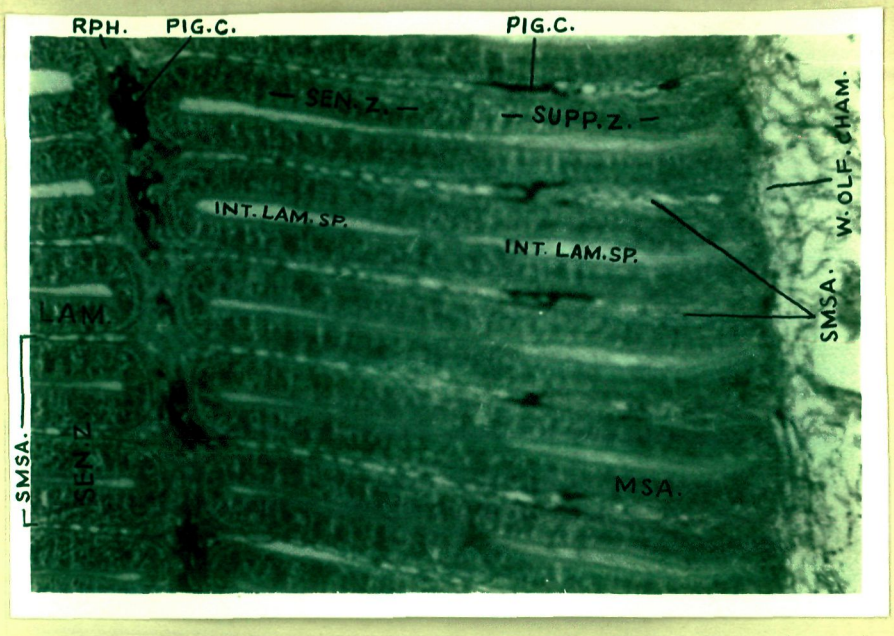

Fig. 72

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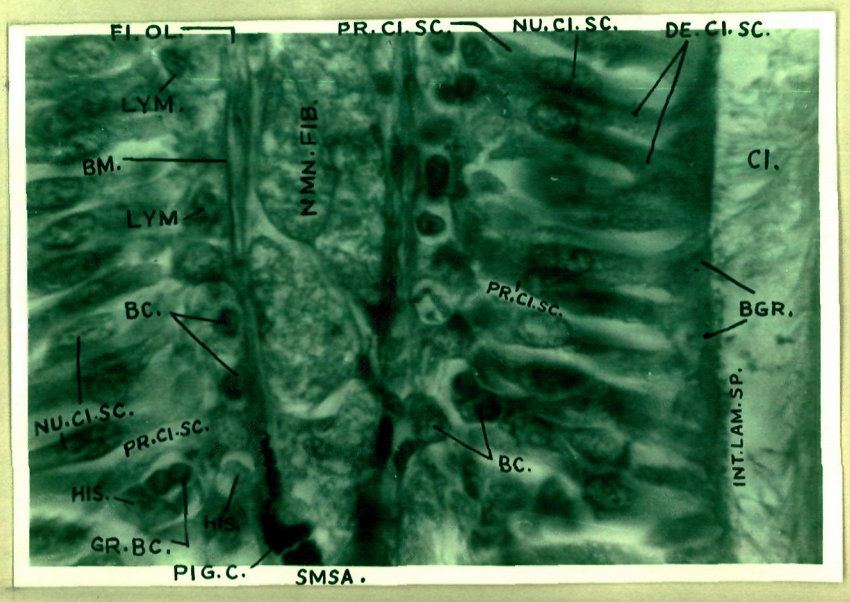

Fig. 73

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HISTOLOGICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF NOTOPTERUS NOTOPTERUS (PALLAS)

The olfactory rosette of N. notopterus bears numerous lamellae arranged transversely on the either sides of rostro-caudually elongated raphe (RPH., Figs. 66, 71, 72). Each lamella comprises of a central core or submucosa (SMSA.) lined on both the sides by the cellular component of the olfactory epithelium or mucosa (MSA., Figs. 70, 71, 72). The distal surface of all the lamellae is uniform and the formation of secondary lamellae is not observed in olfactory epithelium of N. notopterus. Following cellular components have been identified in the mucosa of a lamella: the supporting cells; the receptor cells and the basal cells.

The distribution of the above cellular component is in a peculiar fashion showing a clear cut zonation of the supporting and sensory regions (SUPP. Z AND SEN. Z., Fig. 72). The total absence of goblet cells and rich distribution of the branched pigment cells (PIG. C., Figs. 70, 71, 72, 76, 78) in the connective tissue of the lamella and raphe are also of some significance. On the basis of cellular arrangement and zonation, it is desirable to distinguish an olfactory lamella in the following regions:

The proximal region:

This region extends from the central part of the rosette on either sides of raphe. It is purely a sensory zone supplied with receptor cells and nonciliated supporting cells (NCI. SC.). Sensory zone is lined by the stratified cuboidal olfactory epithelium. The central core is comparatively narrow and consists of areolar connective tissue (Figs. 71, 72, 75, 79, 80, 81).

The distal region:

This region extends from the middle part of the rosette to the lateral wall of the olfactory chamber in both the halves of the rosette. It consists of ciliated columnar epithelium (CI. SC.) and is purely nutritive and supporting in nature. A broad central core is present which is supplied with the dense connective tissue, vascular and nervous components (Figs. 70, 72, 73, 74, 76, 77, 78).

The supporting cell:

The supporting cells can be distinguished in two major types: the nonciliated supporting cells and the ciliated supporting cells.

The first type of supporting cells are nonciliated (NCI. SC.) and are confined into the sensory zone of the olfactory epithelium. They are alternately situated in between the dendrites of the primary neurones with oval nucleus (NU. NCI. SC.)

Fig. 74. Vertical section of the lamella of N. notopterus passing through the supporting zone showing the supply of thick collagen connective tissue fibres, nonmedulated nerve fibre bundle, blood capillary and nearby lying pigment cells. Magnification X 400.

ARE.	Areolae
B.C.	Basal cell
BCP.	Blood capillary
BC. Z.	Basal zone
BM.	Basement membrane
CI.	Cilia
CI. SC.	Ciliated supporting cell
FI. OL.	Filum olfactorium
GR. BC.	Group of basal cells
INT. LAM. SP.	Interlamellar space
NAN. FIB.	Nonmedulated nerve fibre bundle.

Fig. 75. Vertical section of the two lamellae of N. notopterus passing through sensory zone and arrows indicate the presence of olfactory vesicles on the free surface of the lamellae. Magnification X 400.

ARE.	Areolae
FI. OL.	Filum olfactorium
INT. LAM. SP.	Interlamellar space
NCI. SC.	Nonciliated supporting cell
PN.	Primary neurone
SR.	Spindle shaped receptor cell

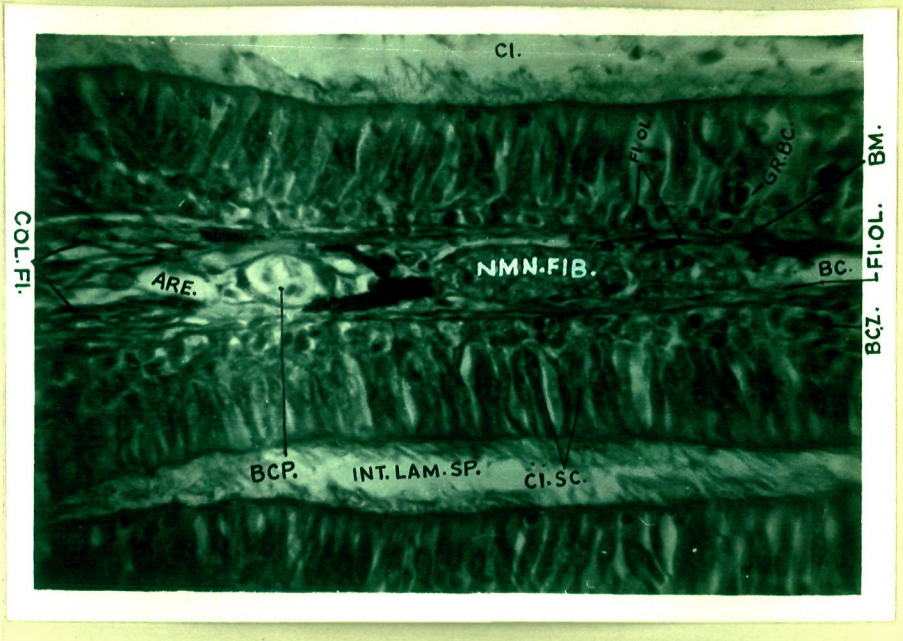

Fig. 74

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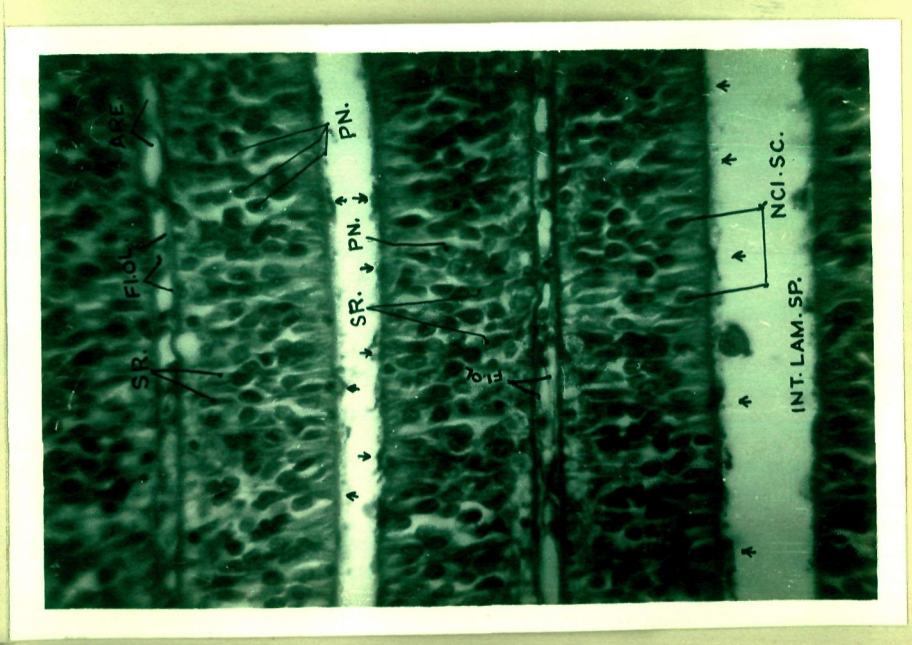

Fig. 75

75

and a short body. The nucleus takes dark stain of the haemotoxyline and is clearly visible. The chromatin and nucleolus are faintly visible. The distal limb of the supporting cells is short but shows a clear appearance among the dendrites of the receptor cells. It is filled with the homogeneous karyoplasm and takes comparatively lighter stain as compared to the surrounding cellular components. The proximal limb of these cells is very inconspicuous and is not clearly visible. At some places of the olfactory epithelium their existence is confused with primary receptor cells because of the abundant supply of these receptorsin the well defined sensory zone (Figs. 71, 75, 79, 80, 81).

Ciliated supporting cells (CI. SC.) are columnar and exceptionally tall forming the supporting and nutritive zone of a lamella in the distal half of the rosette (Fig. 70). They are arranged perpendicular to the basement membrane and are densely ciliated. These cells are made up of two limbs; an inner or proximal and an outer or distal (PR. CI. SC. AND DE. CI. SC.). The former is short and thick extending upto the basal zone while the latter is elongated and extending upto the peripheral surface of the lamella. It ends on the peripheral surface by an expanded tip which bears the bunch of elongated cilia (CI., Figs. 73, 74, 76, 77, 78). The cilia are projected in the interlamellar spaces from both sides forming cluster and their direction of synchronous beating can be seen in the sections. The proximal and

Fig. 76. Transverse section of the lamella of *N. notopterus* showing clusters of olfactory cilia implanted on basal granules. Cilia showing unidirectional beating. Magnification X 1000.

BC.	Basal cell
BGR.	Basal granule
BM.	Basement membrane
CI.	Cilia
DE. CI. SC.	Distal limb of ciliated supporting cell
INT. C. SP.	Intercellular space
LYM.	Lymphoid cell
NON. FIB.	Nonmedulated nerve fibre bundle
NU. CI. SC.	Nucleus of ciliated supporting cell
PIG. C.	Pigment cell
PR. CI. SC.	Proximal limb of ciliated supporting cell

Fig. 77. Transverse section of lamella of *N. notopterus* passing through the supporting zone and showing grouping of basal cells in the preparation of their possible transformation in other cellular content of mucosa. Magnification X 1000.

BC.	Basal cell
BM.	Basement membrane
DE. CI. SC.	Distal limb of ciliated supporting cell
FB. C.	Fibroblast cell
FI. OL.	Filum olfacterium
GR. BC.	Grouping of basal cell
HIS.	Histocytes
PR. CI. SC.	Proximal limb of supporting cell

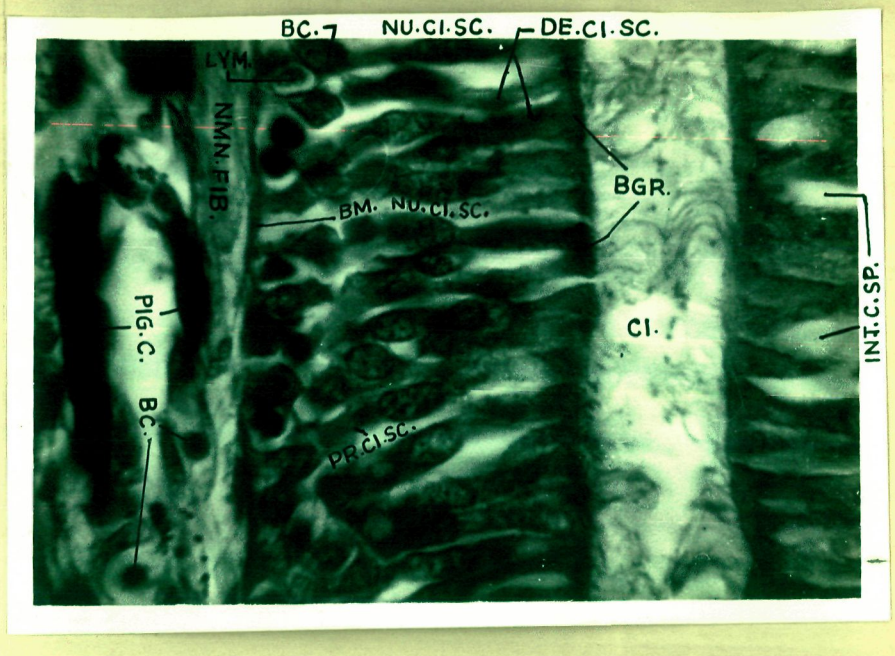

Fig. 76

76

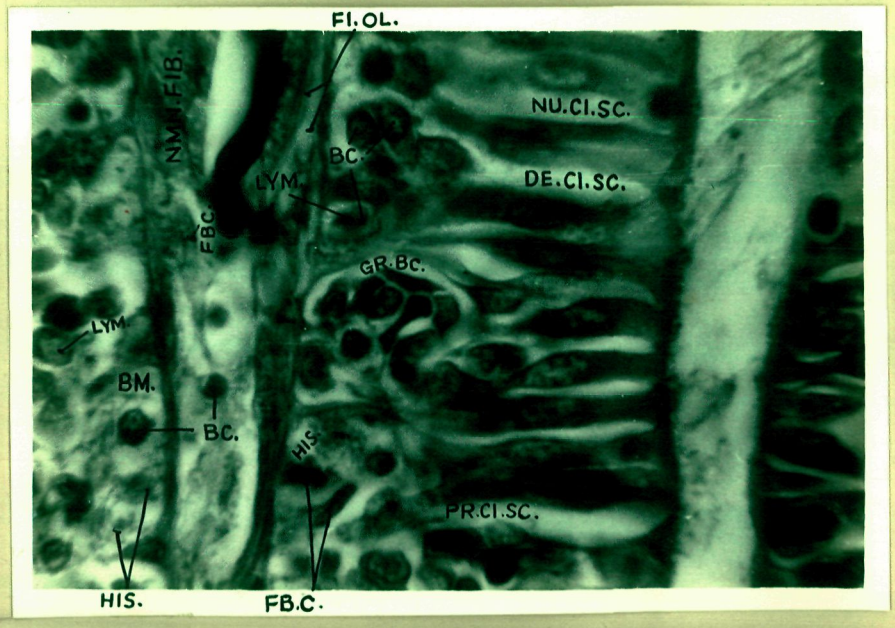

Fig. 77

77

distal limbs of ciliated supporting cells have clear and homogeneous cytoplasm. The distal limb takes comparatively darker stain as compared to the proximal. The columnar supporting cells are negatively muciperous and they do not transform into the mucous secretary goblet cells (Figs. 73, 74, 76, 77, 78).

The distal tip of the ciliated supporting cells bear basal granule (BGR., Figs. 73, 76, 78) associated with cilia which reveals their existence under high magnification. The nucleus (NU. CI. SC.) of the ciliated supporting cells is ovoid in shape and is lodged in the basal zone of the proximal limb. The chromatin material and nucleolus are clearly visible. These cells are not densely arranged and intercellular spaces are seen.

The receptor cells:

On the basis of the shape of nucleus and their position in the olfactory epithelium, receptors can be distinguished into two types. Primary neurones (PN.) and secondary receptor cells or spindle shaped receptor (SR.).

The primary neurones are confined in the sensory zone of the olfactory lamella and invariably separated from one another by the nonciliated supporting cells. The accumulation of these receptor cells in the form of olfactory bud is not observed any where in the olfactory epithelium of N. notopterus. The primary neurones have a bulbous cell body containing more or less

spherical nucleus (NU. PN.). The chromatin material is distributed in the karyoplasm. It takes dark stain of haematoxyline as compared to the surrounding cellular components.

The axon of primary receptor cells is not traceable as an independent element because it establishes synapsis (SY.) with dendrites of the spindle shaped receptors (Figs. 79, 80, 81). The distal or outer margin of the primary receptors give rise to thick and cylendrical dendrites (DN. PN.) whose tips swells to form an olfactory vesicle (OV.) projecting in the interlamellar spaces. The projection of olfactory vesicle in the interlamellar spaces is of varying degree but at some place they form a well marked triangular projection. The appearance of the microvilli (MVL) from the vesicle can easily be observed (Figs. 75, 79, 80, 81).

The spherical nuclei (NU. PN.) of the primary neurones form an ill defined zone between the nuclei of the basal cells and inner sides of the nonciliated supporting cells. The nuclei of some primary neurones are situated rather deep more close to basal zone, consequently having long and narrow dendrites (DN. PN.). The other lie less deep bear thick and short dendrites and finally their nuclei lie comparatively superficial more or less at the level of the primary supporting cells. Commonly these receptor cells are situated superficially with short and broad dendrites (Figs. 71, 79, 80, 81).

Fig. 80. Transverse section of the lamella of N. notopterus passing through the sensory zone. Specific spindle shaped receptors cells are observed which do not establish synaptic contact but send an elongated dendrite, ending in the form of olfactory vesicle on the free surface of lamella. Arrows indicate the pasthways of the dendrites and axon. Magnification X 1000.

ARE.	Areolae
AX. SR.	Axon of spindle shaped receptor cells
BC.	Basal cell
DN. SR.	Dendrite of spindle shaped receptor cell
FI. OL.	Folium olfactorium
MOV.	Microvilli
NIC. SC.	Nonciliated supporting cell
OV.	Olfactory vesicle
PN.	Primary neurone
SR.	Spindle shaped receptor cell

Fig. 81. Transverse section of the lamella of N. notopterus passing through sensory zone showing elongated dendrite of spindle shaped receptor cells which ends in the form of olfactory vesicle. Some synaptic contacts are also observed. Arrows indicate the pathways of the dendrite, axon and also to the synaptic contacts. Magnification X 1000.

AX. SR.	Axon of spindle shaped receptor cells
BC.	Basal cells
DN. SR.	Dendrite of spindle shaped receptor cells
HIS	Histocytes
NCI. SC.	Nonciliated supporting cells
OV.	Olfactory vesicle
PN.	Primary neurones
SR.	Spindle shaped receptor cells
SY.	Synaptic contact.

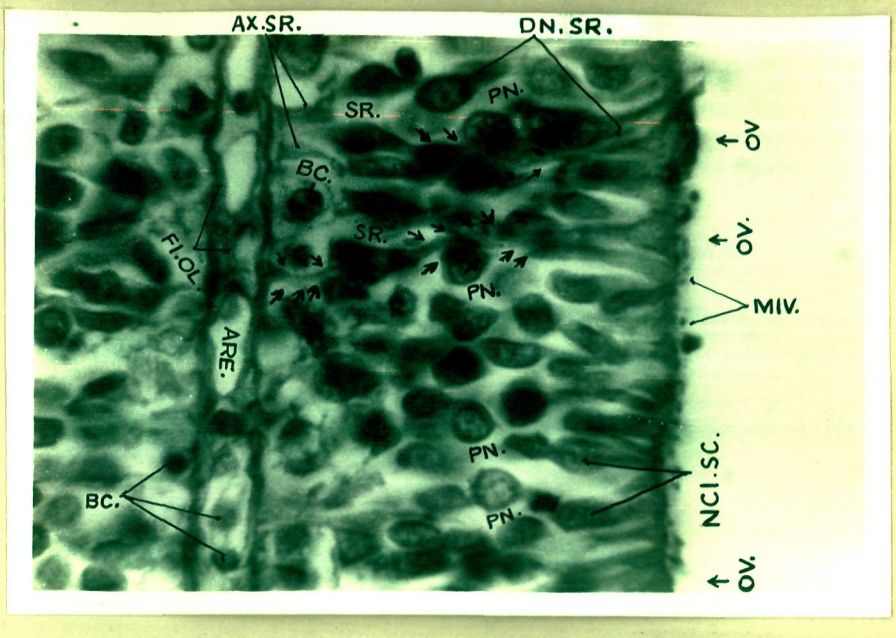

Fig. 80

80

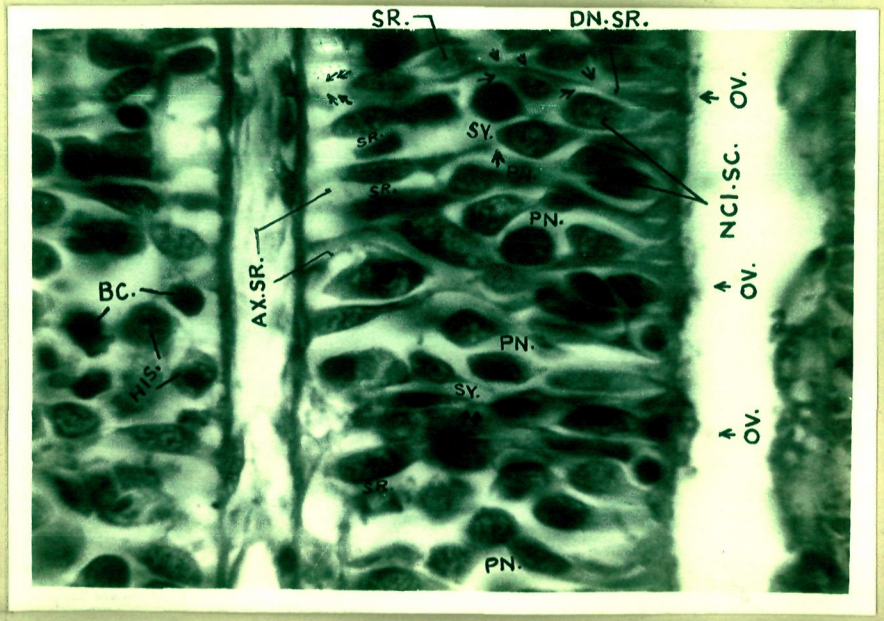

Fig. 81

81

The spindle shaped receptors have elongated body with scanty cytoplasm surrounding the elongated and oval nucleus (NU. SR.). The nucleus takes a less stain with haemotoxyline as compared to the nucleus of primary receptor cells. It has a conspicuous nucleolus with scattered chromatin material in karyoplasm. A thin proximal process of the axon (AX. SR., Figs. 79, 80, 81) extend upto the basement membrane where they aggregate to form folium olfactorium (FI. OL. Figs. 71, 75, 79, 80). The dendrites are not seen extending upto the peripheral surface but establish synaptic contact (SY., Figs. 79, 80, 81) with the axon of primary neurones. It is difficult to trace synaptic contact between primary and secondary receptor cells but, however, few synaptic contacts are visible due to the careful sectioning and staining of the material. The presence of these receptor cells below the primary neurones define them as secondary or spindle shaped receptors.

A peculiar type of the receptor cells are accidentally encountered in the olfactory epithelium and they are very deeply situated. They have oblong nucleus with enormously elongated filamentous dendrites (DN. SR.) which has very expanded olfactory vesicle but it does not project into the interlamellar spaces. This expanded tip bears three or four microvilli, projecting into the interlamellar space. The axon (AX. SR.) is equally clear and extends upto the folium olfactorium (FI. OL., Figs. 71, 73, 74, 76, 77, 78, 79, 80), along the basement membrane.

Axon and dendrites of the receptor cells are eosinophilic and take equally good stain. They can be identified as spindle shaped receptor cells which do not make synaptic contacts with primary receptors but send their dendrites freely upto the peripheral surface of olfactory lamella (Figs. 80, 81).

The basal cells:

The basal cells (BC.) are uniformly present in the supporting zone in a single layer just above the basement membrane (Figs. 71, 73, 74, 76, 77, 78). They are scantly present in the basal zone but at some places their aggregation (GR. BC., Figs. 73, 74, 77, 78) can be seen which can be understood as a preparation of the formation of some cellular component of the olfactory epithelium. The nucleus of the basal cell is rounded with clearly visible chromatin material and decentric nucleolus. In the sensory zone their distribution is irregular among the nuclei of receptor cells. The cell wall of the basal cells show irregular surface with very small amount of the cytoplasm around the nucleus. They are also encountered in the central core of the lamella. The lymphoid cells (LY.), histocytes (HIS.) and fibroblast cells (FB.C.) are present among the basal cells with irregular cell wall and darkly staining nuclei (Figs. 73, 76, 77, 78).

The central core or submucosa:

On the basis of the clear cut zonation of the olfactory epithelium the central core or submucosa (S.MSA.) can also be distinct into the proximal central core or submucosa of sensory zone and the distal central core or submucosa (S.MSA.) of the supporting zone. The former is narrow and constricted while the latter is broad and expanded. The central core or submucosa in both the zonesis lined by the well defined straight basement membrane. The sensory zone of the olfactory epithelium is lined by the areolar connective tissue (ARE., Figs.71, 80). It is made up of longitudinally extending collagen fibres (COL. FI.) enclosing areolae. The rare supply of fibroblast (FB. C. Figs. 77, 78) basal and histocyte cell are seen in this region. This region is nonvascular and collagen fibres are devoid of pigment cells. Areolae are considerably spacious and are lined by the thick collagen fibres. Follium olfactoria extend along the basement membrane which joins nonmedulated nerve fibres (NMN. FI.) in supporting zone. The central core or submucosa of supporting zone is made up of dense collagen connective tissue and is richly supplied with blood capillaries and nonmedullated nerve fibres (Figs. 73, 74, 76, 78). The collagen fibres are compactly arranged intengling elongated branched pigment cells (PIG. C., Figs. 74, 76, 78). The nonmedullated nerve bundles are present in supporting zone at a definite level in all the lamellae and probably they might be joining the olfactory nerve passing through the ventral surface of the rosette (Fig. 73). The

pigment cells are always seen in surrounding the blood capillary and nonmedullated nerve fibres. The dense connective tissue in the distal region of the olfactory lamellae may help in binding the blood capillary and nerve supply as well as it also acts as turger to provide strength to this region. The basal cells and fibroblasts can also be observed very rarely in the matrix of connective tissue of the supporting zone (Fig. 76, 77, 78).

The raphe:

The raphe is composed of thick nonciliated columnar epithelium, devoid of sensory cells and possess enormously developed central core or submucosa. The epithelial lining and central core or submucosa is separated by a well demarcated basement membrane. The peripheral inner or proximal epithelial lining of the raphe in N. notopterus bears three or four thick layers of basal cells and also has a single layer of short columnar cells (NCI. SC., Figs. 82, 83).

The central core or submucosa(SMSA.) is densely supplied with the collagen fibres (COL. FI., Fig. 71). The yellow fibres are also seen intermingled with these fibres. The rich distribution of pigment cells (PIG. C.) is observed which are entengled among the fibres. The fibroblast (FB. C.) and basal cells (BC.) cells are also observed in the ground substance of connective tissue. Nonmedullated nerve fibres extend along the basement

Fig. 82. Vertical section of raphe of N. notopterus showing blood sinus and lamellae attached on its either sides. Magnification X 100.

ARE.	Areolae
BL. C.	Blood cell
BL. SI.	Blood sinus
BM.	Basement membrane
LAM.	Lamella
PIG. C.	Pigment cell
RPH.	Raphe
SMSA.	Submucosa

Fig. 83. Transverse section of raphe of N. notopterus. Magnification X 400.

ARE.	Areolae
BC.	Basal cell
BC. Z.	Basal zone
BL. SI.	Blood sinus
CON. TI.	Connective tissue
CON. TI. FI.	Connective tissue fibres
FB. C.	Fibroblast cells
NCI. SC.	Nonciliated supporting cells
PIG. C.	Pigment cell
SC. Z.	Supporting zone.

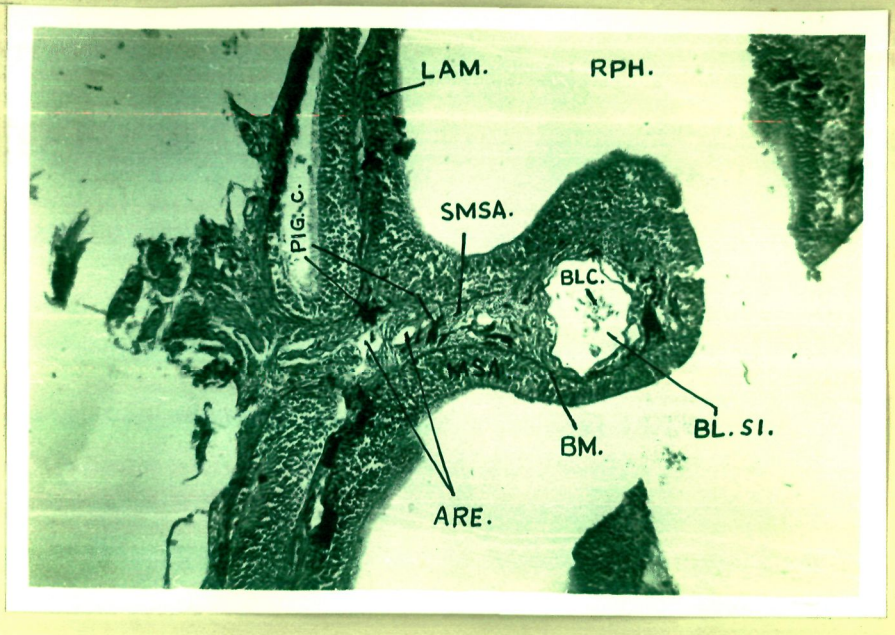

Fig. 82

82

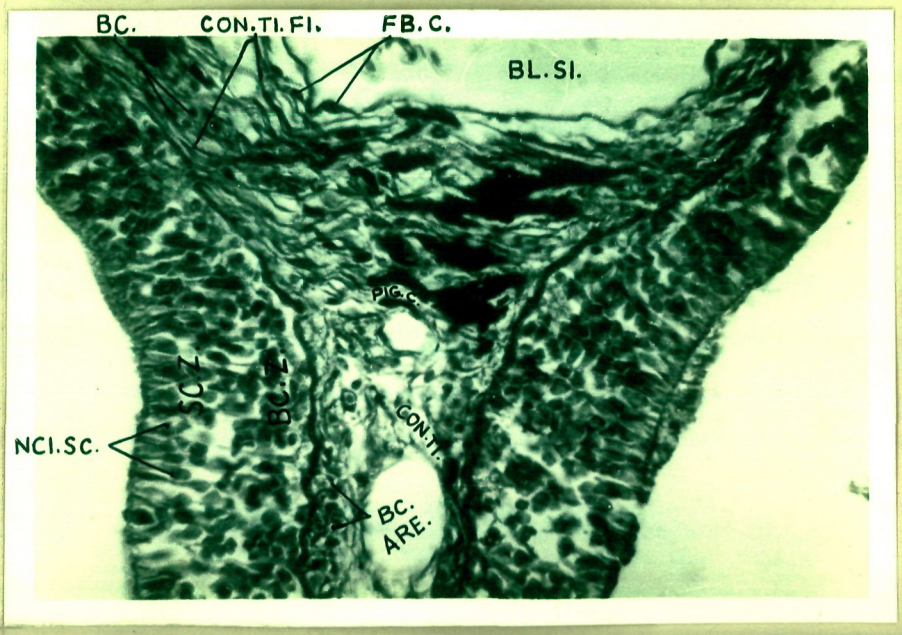

Fig. 83

83

membrane which finally joinsto the medullated nerve fibres of the olfactory nerve. In the centre,two or three areolae (ARE.) can be seen which demarcate the connective tissue of raphe of N. notopterus as areolar collagen connective tissue. A blood sinus extends in the centre of the raphe giving the supply to the lamellae by its finner branches. The basal zone (BC. Z.) is made up of three to four layers of basal cells. These consists of rounded nucleus with irregular cell wall with scanty cytoplasm around it. The columnar cells (NCL. SC.) extend from the basal zone to the periphery of raphe. The nucleus gets confined towards the basal zone and occupies the proximal leaving the columnar distal limb projecting to the surface of raphe. The nuclei of all the columnar cells are lying at definite level and take comparative darker stain (Figs. 82, 83).

Fig. 84. Lateral view of head of *M. armatus armatus*.

POST. NAS. OP. Posterior nasal opening

ROST. APP. Rostral appendage.

Fig. 85. Dissection of the head from lateral side to show rosette in situ of *M. armatus armatus*.

POST. NAS. OP. Posterior nasal opening

RE. Rosette

ROST. APP. Rostral appendage

ROST. APP.

Fig. 84

84

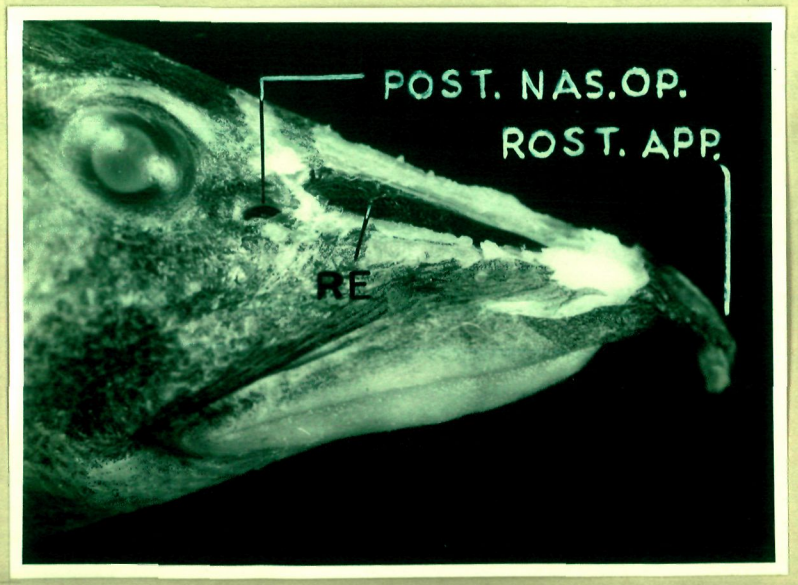

Fig. 85

85

Fig. 86A. Diagram of the lateral view of the head of *M. armatus armatus*.

Fig. 86B. Diagram of the dissection of lateral view of ak head to show rosette, infranasal chamber, accessory sac and anterior nasal tube in *M. armatus armatus*.

Fig. 86C. Ventral view of trilobed rostral appendage of *M. armatus armatus*.

Fig. 86D. Diagram of posterior aperture of *M. armatus armatus* to show dorsal and ventral lips.

Fig. 86E. Diagrammatic sketch of the rosette of *M. armatus armatus*.

Fig. 86F. A set of 1-39 lamellae of one row of ventral half of the rosette.

ANT.	Anterior
ANT. ACC. NAS. SAC.	Anterior accessory nasal sac
ANT. NAS. OP.	Anterior nasal opening
ANT. NAS. TEN.	Anterior nasal tentacle
ANT. NAS. TUBE	Anterior nasal tube
DORS. LIP.	Dorsal lip
INTG.	Integument
INT. LAM. SP.	Interlamellar space
LAM.	Lamella
OLF. NE.	Olfactory nerve
OP. INF. NAS. CHAM.	Opening of infranasal chamber
OP. RE.	Opening of rosette
PIG. SHE.	Pigment sheath
POST.	Posterior
POST. NAS. OP.	Posterior nasal opening
RE.	Rosette
VEN. LIP.	Ventral lip.

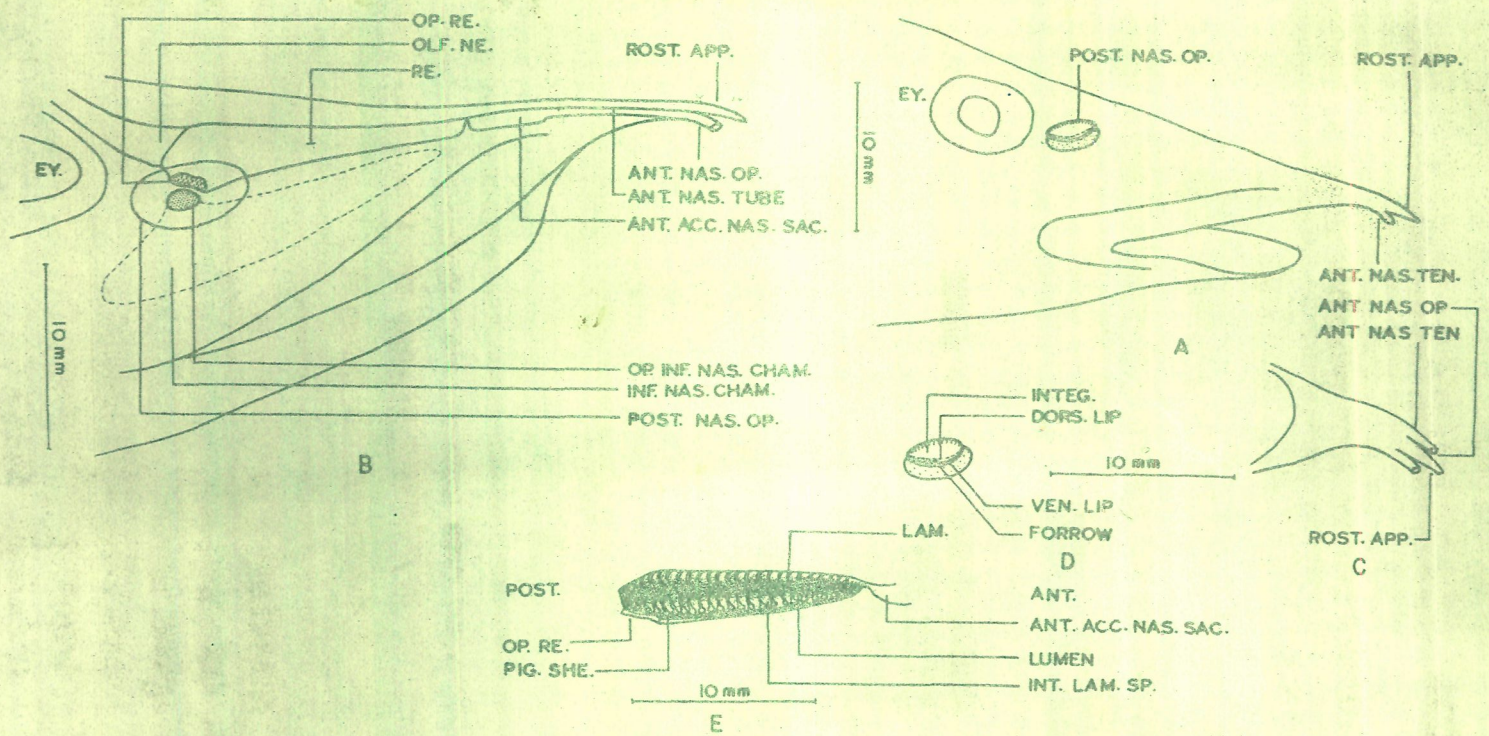
OP. RE.
OLF. NE.
RE.
ROST. APP.
EY.
ANT. NAS. OP.
ANT. NAS. TUBE
ANT. ACC. NAS. SAC.
10 mm
OP. INF. NAS. CHAM.
INF. NAS. CHAM.
POST. NAS. OP.
B
POST. NAS. OP.
ROST. APP.
EY.
10 mm
ANT. NAS. TEN.
A
ANT. NAS OP
ANT NAS TEN
INTEG.
DORS. LIP
10 mm
VEN. LIP
FORROW
D
ROST. APP.
C
LAM.
POST.
ANT.
ANT. ACC. NAS. SAC.
OP. RE.
PIG. SHE.
LUMEN
INT. LAM. SP.
10 mm
E
1
24
25
39
5 mm
F

FIG. 86.

ANATOMICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF MASTACEMBALUS ARMATUS ARMATUS GUNTHER

The olfactory chamber of M. armatus armatus is enormously developed, occupying the entire dorso-lateral surface of the head. It is posteriorly broad and gradually tapers towards the anterior side. The chambers are communicated out side by a pair of nasal openings and are designated as the anterior and posterior nasal openings (ANT. NAS. OP. AND POST. NAS. OP.) by virtue of their respective positions in head (Figs. 84, 86A, 86B).

The anterior nasal opening is tubular (ANT. NAS. TUBE, Figs. 97) and opens on either side of fleshy rostral appendage (ROST. APP., Figs. 84, 85, 86A, 86B, 86C) by a small delicate tentacle (ANT. NAS. TEN., Figs. 86A, 86B, 86C). The anterior part of the tubular anterior nasal opening along with thin covering of the integument form the tentacle like structure which in natural condition is directed downwards and forwards (Figs. 86A, 86B, 86C). The internal lining of the anterior nasal tube is nociliated and possess cell processes (C. PRO., Figs. 97, 99). It is posteriorly modified into anterior accessory sac (ANT. ACC. NAS. SAC., Figs. 97, 100). The sac is communicated with lumen of the olfactory rosette by a constricted passage (TO RE. LUM., Figs. 97, 100).

Fig. 87. Diagram of the lateral view of skull of *M. armatus armatus*. (Posterior region is not drawn).

DEN.	Dentary
ETH.	Ethmoid
FRON.	Frontal
HYO.	Hyomandibular
IOPR.	Inter operculum
LAC.	Lacrymal
LETH.	Lateral ethmoid
MAX.	Maxilla
MPT.	Metapterygoid
NAS.	Nasal
OPR.	Operculum
PAL.	Palatine
PAS.	Parasphenoid
PREMAX.	Premaxilla
PRE. OPR.	Preoperculum
POST. NAS. OP.	Posterior nasal opening
PTR.	Pterygoid
Q.	Quadrate
ROST. CART.	Rostral cartilage
SOPR.	Suboperculum
SYM.	Symplectic

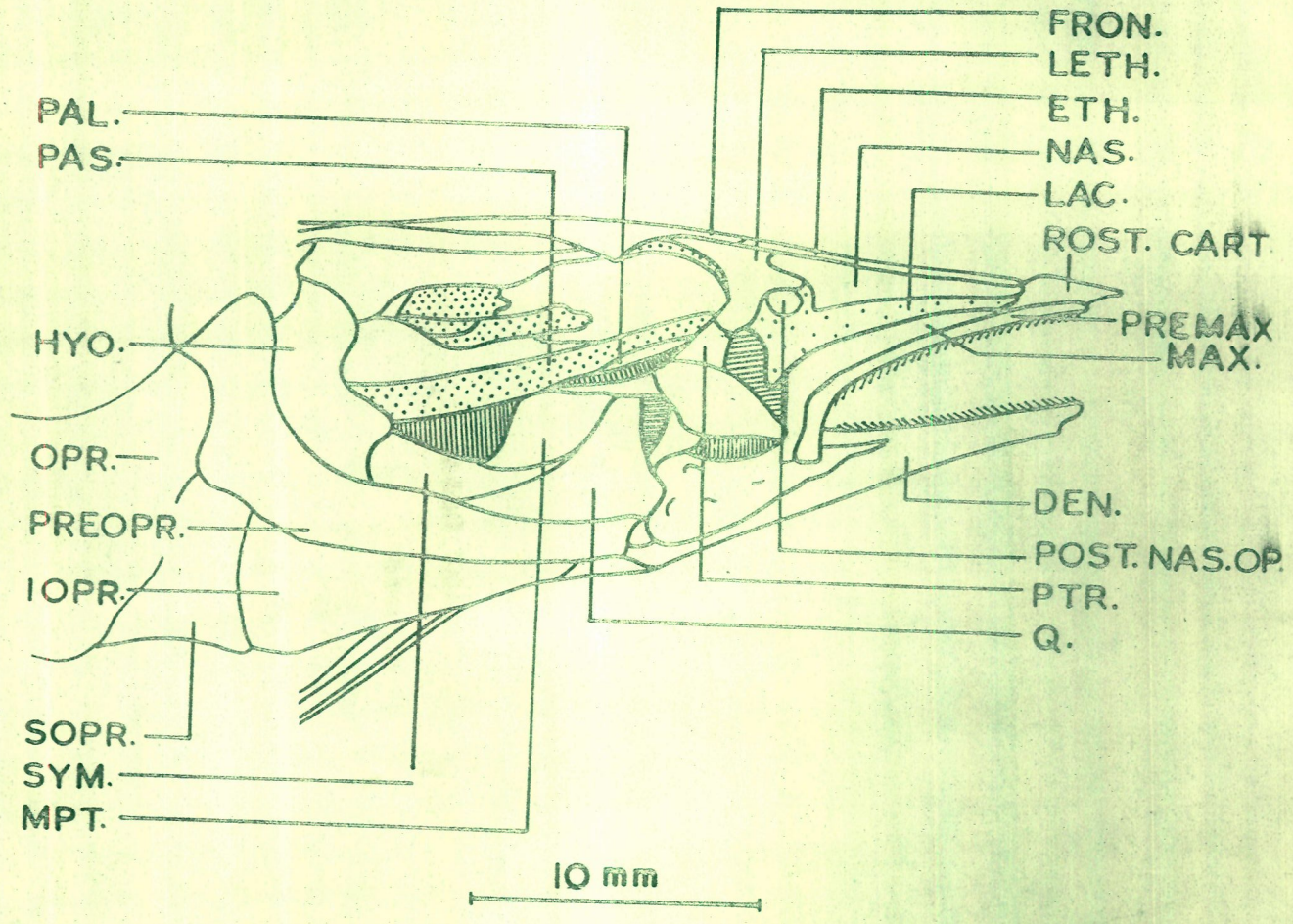
FRON.
LETH.
ETH.
NAS.
LAC.
ROST. CART.
PREMAX
MAX.
DEN.
POST. NAS. OP.
PTR.
Q.
PAL.
PAS.
HYO.
OPR.
PREOPR.
IOPR.
SOPR.
SYM.
MPT.
10 mm

FIG. 87.

The posterior nasal opening lies infront and ventrally to the eye orbit which is demarcated by an area lined by a loose integument (POST. NAS. OP., Figs. 84, 86A, 86B, 86C). It is a slit like opening constituted of ventral and fdorsal lips (VEN. LIP AND DOR. LIP, Fig. 86D). The former gets expanded over the latter giving a shape of valve. In the natural condition the posterior nasal opening makes valvular movements and is alternately pushing out the surface area towards the outside. The posterior nasal opening lies just above the crescentric aperture of infranasal chamber (OP. INF. NAS. CHAM., Figs. 86B), and the aperture of olfactory rosette (OP. RE., Figs. 86B, 86E).

In the fish of 500 mm total length, the anterior and posterior nasal openings olie at a distance of 23 mm. The area demarcating the posterior nasal opening in 2.925 mm in length and 1.872 mm in width. The anterior nasal tube is 3.510 mm in length opening out by an opening of 0.284 mm in diameter.

The olfactory rosette of M. armatus armatus is a peculiar type and is composed of dorsal and ventral concave halves (DOR. H. AND VEN. H., Fig. 90) which are lodged on each other by their lateral hinges (LAT. HIN., Fig. 90), forming a "barrel shaped" structure (Figs. 85, 86B, 89). The epithelium of both the halves is thrown into a number of projections or lamellae (LAM.), arranged in a fashion that a continuous central cavity or lumen

Fig. 88. Diagram of the dissection of the head from the dorsal side of *M. armatus armatus* to show the relationship of brain with rosette.

CE.	Cerebellum
EY.	Eye
OLF. BL.	Olfactory bulb
OLF. LO.	Olfactory lobe
OLF. NE.	Olfactory nerve
OP. LO.	Optic lobe
RE.	Rosette

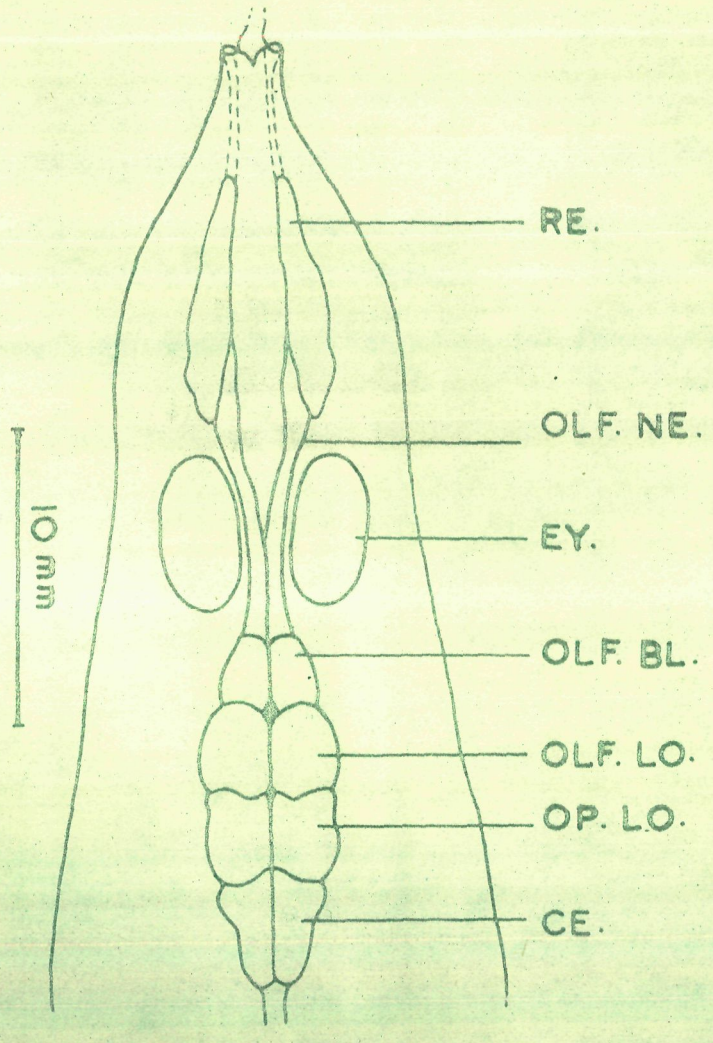

FIG. 88.

(LUM.) is formed through out the length of the rosette (Fig. 90). The lumen is anteriorly continued in the form of an anterior tubular nasal opening and opens posteriorly into the infranasal chamber by an independent aperture (OP. NE., Fig. 86B) just below the posterior nasal opening. The olfactory rosette is enormously elongated having narrow anterior end which gets broadened posteriorly. It is thickly coated by a pigment sheath and is outwardly giving a dark black appearance (Figs. 85, 86B, 86E).

The lamellae (LAM., Fig. 86F, Nos. 1-39) are keel shaped and their distal ends are projected into the lumen of the rosette. They are grown on the thickened epithelium and maintain interlamellar spaces (INT. LAM. SP., Figs. 86E, 89, 90) in between them. The lamellae are short and pointed on the anterior side but posteriorly become broad. The alternate arrangement of the lamellae in both the halves of the rosette is seen opposite to each other. The pigmentation is localized at the base and lamellar elongation is devoid of pigment cells (1-39 one row of lamellae from the ventral half of the rosette, Fig. 86F).

The infranasal chamber lies ventrally to the olfactory rosette which extends postero-anteriorly just below the lacrymal bone. It (INF. NAS. CHAM., Fig. 86B) acts as a reservior of water to irrigate the olfactory lamellae and is made up of thin and flattened epithelium of the buccal cavity.

The dorsal and dorso-lateral sides of the olfactory chambersare covered by the nasal bone (NAS.). It becomes sufficiently elongated and flattened to cover the entire olfactory rosette from the dorsal side. Anteriorly nasal flank covers the anterior two-third of the median ethmoid (ETH.). The anterior tubular nasal opening and the tentacle transverse through the narrow canal which form the tapering anterior end of nasal bone. The olfactory rosette as well as fnfranasal chamber remain covered by thin membranous wall of the buccal cavity (Fig. 87).

The olfactory nerves pass through a foramen which is constituted by the posterior part of median ethmoid (ETH.) separating the lateral ethmoid (LaTH.) in the posterior region of the olfactory chamber (Fig. 87).

After dissecting the fish from dorsal side of the head and removing carefully the frontals, lateral ethmoid, median ethmoid and nasal,exposedthe relationship of the rosette with brain. The olfactory bulbs (OLF. BL.) are situated on the hemisphere of forebrain against the olfactory lobes (OLF. LO.). All the nerve fibres of the olfactory rosette unite to form olfactory nerve (OLF. Na.) which traverses through inner margin of rosette and they finally join the lobe after passing the olfactory foramen. The olfactory nerves are exceptionally thick and are composed of medullated nerve fibres. The telencephalon with olfactory bulb and lobes is well developed and

Table 4 : Notacanthus nasutus nasutus (Nose-fish)

S.No.	Total Length	No. of lamellae Rosette Right	Left	Total length of the Brain	Length of Mesencephalon	Length of Telencephalon	Ecological coefficient (Through lobes of Brain) Length of Telencephalon X 100 / Length of Mesencephalon	Retinal area of both eyes	Olfactory area of both rosette	Ecological coefficient (Through area) Olfactory area X 100 / Retinal area
1.	324 mm	152	152	11.12 mm	2.31 mm	2.72 mm	117.74	16.68 mm^2	1105.04 mm^2	6624.06
2.	395 mm	192	192	15.00 mm	2.60 mm	3.04 mm	115.01	17.70 mm^2	1241.28 mm^2	7012.88
3.	465 mm	216	216	16.00 mm	2.70 mm	3.15 mm	112.00	24.60 mm^2	1578.80 mm^2	6417.88
4.	500 mm	216	216	17.00 mm	2.92 mm	3.27 mm	111.98	24.60 mm^2	1662.92 mm^2	6759.82
5.	625 mm	240	240	17.50 mm	3.01 mm	3.68 mm	122.26	32.20 mm^2	2203.12 mm^2	6857.50

gives a dominating impression over the other lobes of the brain (Table 4). The optic lobes (OP. LO.) are considerably reduced. The brain is laterally compressed and a marked increase with respect to the rise of the fish (Table 4, Fig. 88).

Ecological co-efficient:

Usually two method are employed for calculating the ecological co-efficient of olfactory and optic faculties of M. armatus armatus for making approximate assessment of the capacity of these two faculties from the anatomical point of view.

Five fishes of different sizes ranging from 324 mm to 625 mm are selected for calculating the ecological co-efficients. The number of lamellae and the length of brain increases successively with the size of the fish. The length of the mesencephalon ranges from 2.31 mm to 3.01 mm and that of telencephalon from 2.72 mm to 3.68 mm which indicates that the olfactory centre is more developed than the optic tectum (Table 4).

The area of two retinae ranges from 16.68 mm^2 to 32.20 mm^2 and that of two rosettes from 1105.04 mm^2 to 2208.12 mm^2 (Table 4). This shows that the value of the area of two retinae stands insignificant as compared to the area of the two rosettes

showing better developed olfactory faculty. The olfactory centre in the brain also exhibits marked domination over the optic centre. It is now clear that the fish under study is a "nose-fish" and sense of olfaction plays an important role in the habit of the fish. The fish lives in mud tubes or in dark places where olfactory faculty is utilized for locating the food material and fright reactions etc.

The route of water circulation through the olfactory chamber of M. armatus armatus:

The constant valvular movement of the surface of the posterior nasal opening synchronously with the opercular movement create an antero-posterior suction pressure which invites water current from the anterior nasal opening. The water current is brought to the lumen of the rosette via the tubular passage of the anterior nasal tube and anterior accessory nasal sac (Figs. 86B, 97, 99, 100) where from it flows antero-posteriorly due to the unidirectional movement of cilia of the lamellar surface (Cl., Figs. 91, 92, 93, 94, 96). It takes a course of whirriling antero-posterior flow into the barrel shaped olfactory rosette and goes out by the postero-ventral aperture which lies under-neath the posterior nasal opening and coincciding to the aperture of infra-nasal chamber. The water current circulates through the infranasal chamber before its final expulsion from the posterior nasal opening. The mud and

other foreign materials are intengled in the accessory sac by the mucous secretion and mud free water is allowed in the lumen of tubular rosette (Figs. 97, 99, 100). The accessory sac is cleaned by the reverse water current created by the compression of infranasal chamber and closing of the posterior nasal opening. It is an additional device for this mud dwelling fish where olfactory passage is repeatedly cleaned by the reverse water current.

In this way the circulation of water takes longer route of transportation through the olfactory chamber in A. armatus armatus as compared to other fishes studied so far (Fig. 868).

Fig. 89. Horizontal section of "barrel shaped" rosette of *M. armatus armatus*, passing through few lamellae. Arrow indicates the passage of lumen to anterior accessory sac. Magnification X 100.

BL. SI.	Blood sinus
BL. VE.	Blood vessel
DE. LAM.	Distal end of lamella
G.	Goblet cell
INT. LAM. SP.	Interlamellar space
LUM.	Lumen
MSA.	Mucosa
PIG. SH.	Pigment sheath
SMSA.	submucosa

Fig. 90. Transverse section of "barrel shaped" rosette of *M. armatus armatus* showing dorsal and ventral halves with their lateral hinges. Two rows of lamellae are seen in each half. Magnification X 100.

BL. SI.	Blood sinus
DE. LAM.	Distal end of lamella
DOR. H.	Dorsal half
INT. LAM. SP.	Interlamellar space
LAT. HIN.	Lateral hinges
LUM.	Lumen
PIG. SH.	Pigment sheath
VEN. H.	Ventral half.

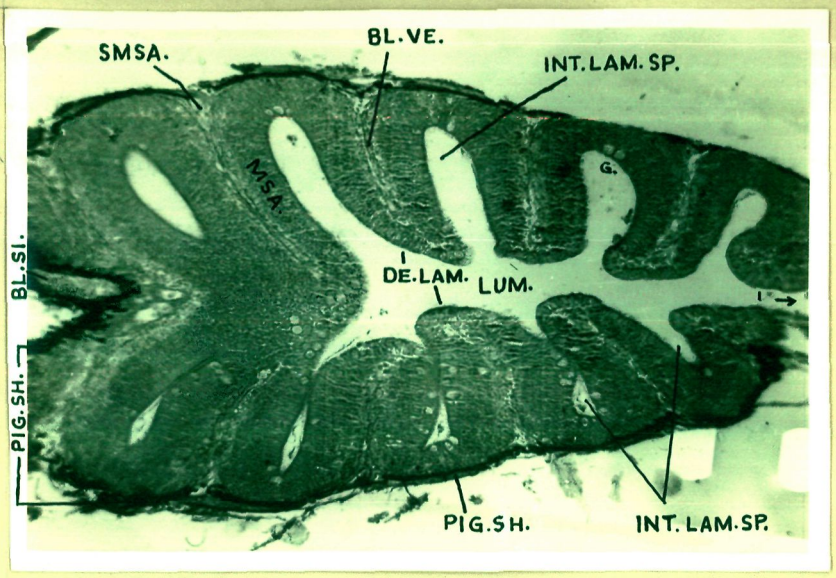

Fig. 89

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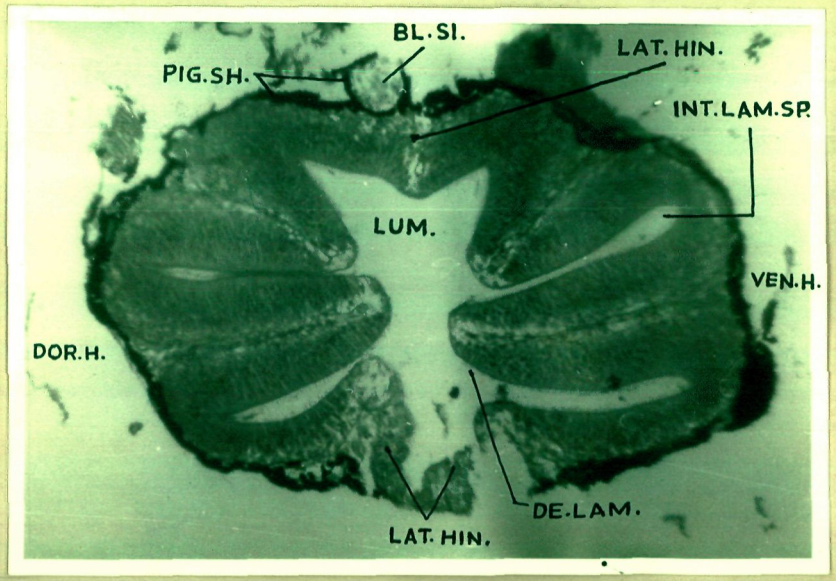

Fig. 90

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HISTOLOGICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *MASTACEMBALUS ARMATUS ARMATUS* GUNTHER

The olfactory rosette of *M. armatus armatus* is barrel shaped (RE., Figs. 85, 86B) which is made up of dorsal and ventral halves (DORS. H. AND VEN. H.), fitted on each other by their lateral hinges (LAT. HIN., Fig. 90). Both the halves give rise numerous folds or lamellae (LAM.) from their respective surfaces and enclose a continuous central cavity or lumen (LUM., Figs. 89, 90). The interlamellar spaces (INT. LAM. SP.) are maintained in between two lamellae. The central cavity or lumen extends anteriorly into the anterior nasal tube (ANT. NAS. TUBE) while posteriorly communicated out side by the posterior nasal opening (Fig. 86B). The rosette is surrounded by a thick dense connective tissue sheath which shows rich distribution of the pigment cells (PIG. SH., Figs. 85, 89, 90), giving it a dark black appearance. The blood and nervous supply are also encircled independently by the pigment sheath.

The olfactory nerve enters through the olfactory foramen and extends along the inner surface of the rosette, distributing its nerve fibres in between various folds or lamellae. The orbito-nasal artery runs along the rosette and supplies its branching to the lamellae through the central core or submucosa (SMSA.) of each lamella. The blood is returned from the rosette through orbito-nasal vein and thus submucosa of every lamellae is

Fig. 91. Vertical section of lamella of *M. armatus* *armatus* showing the supply of two blood vessel in the submucosa and pigment sheath on the base. Magnification X 400.

BC.	Basal cell
BL. VE.	Blood vessel
CI.	Cilia
CI. SC.	Ciliated supporting cell
CON. TI.	Connective tissue
MIG.	Micro-or migratory goblet cell
MSA.	Mucosa
PIG. SH.	Pigment sheath
SMSA.	Submucosa.

Fig. 92. Vertical section of the lamella of *M. armatus* *armatus* showing nonmedullated nerve fibres bundle in the mucosa. Submucosa is comparatively broad. Magnification X 400.

BC.	Basal cell
CI.	Cilia
CI. SC.	Ciliated supporting cell
CON. TI.	Connective tissue
FIOL.	Folium olfactorium
MIG.	Micro- or migratory goblet cells
NMN. FIB.	Nonmedullated nerve fibre bundle.

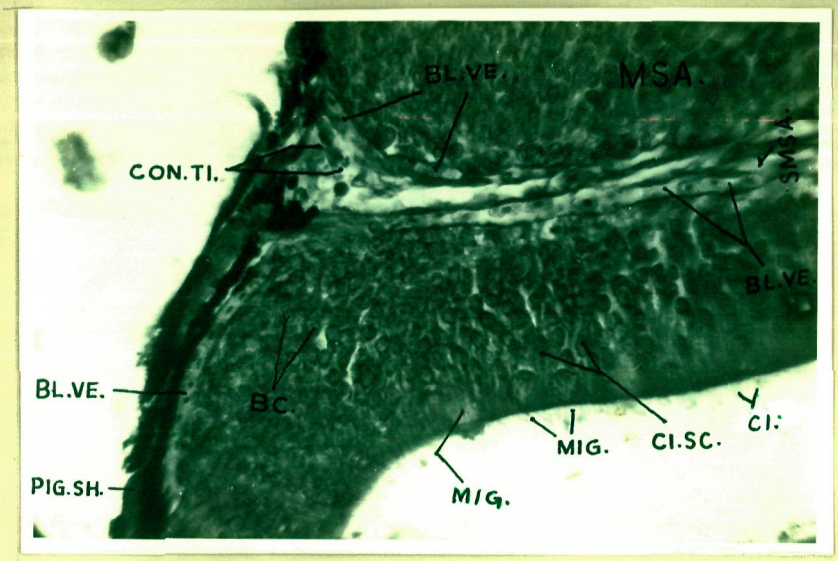

Fig. 91

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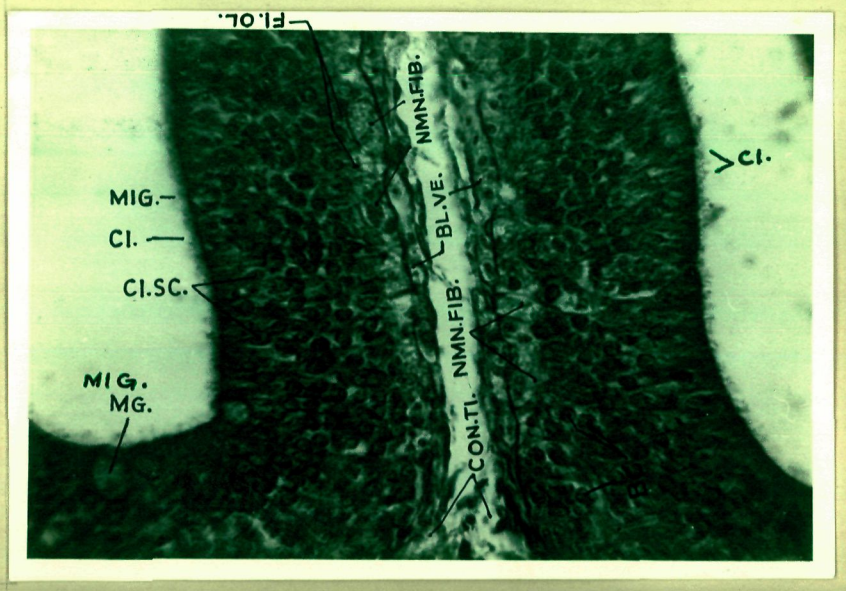

Fig. 92

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Fig. 93. Transverse section of lamella of *M. armatus armatus* passing through the proximal region and showing rich distribution of primary neurones. Olfactory vesicle and olfactory cilia are visible. Goblet cell is present deep in mucosa showing migratory tendency. Arrows indicate the pathways of dendrite and axon. Magnification X 1000.

BC.	Basal Cell
BM.	Basement membrane
CI.	Cilia
CI. SC.	Ciliated supporting cells
MIG.	Migratory goblet cell
MU.BCC	Mucciperous basal cell
NMN. FIB.	Nonmedulated nerve fibre bundle
NU. CI. SC.	Nucleus of ciliated supporting cells
NU PN.	Nucleus of primary neurone
NU. SR.	Nucleus of spindle shaped receptor cell
OCI.	Olfactory cilia.
OV.	Olfactory vesicle
PIG. SH.	Pigment sheath
T. SC.	Transitionary exporting cells

Fig. 94. Transverse section of lamella of *M. armatus armatus* passing through middle region. Magnification X 1000. Arrows indicate pathways of dendrites.

BL. C.	Blood cells
BL. VE.	Blood vessel
CI.	Cilia
DE. CI. SC.	Distal limb of ciliated supporting cell
MU.	Mucous
NU. CI. SC.	Nucleus of ciliated supporting cell
NU. MIG.	Nucleus of migratory goblet cell
NU. NCI. SC.	Nucleus of nonciliated supporting cell
NU. PN.	Nucleus of primary neurone
NU. SR.	Nucleus of spindle shaped receptor cell.

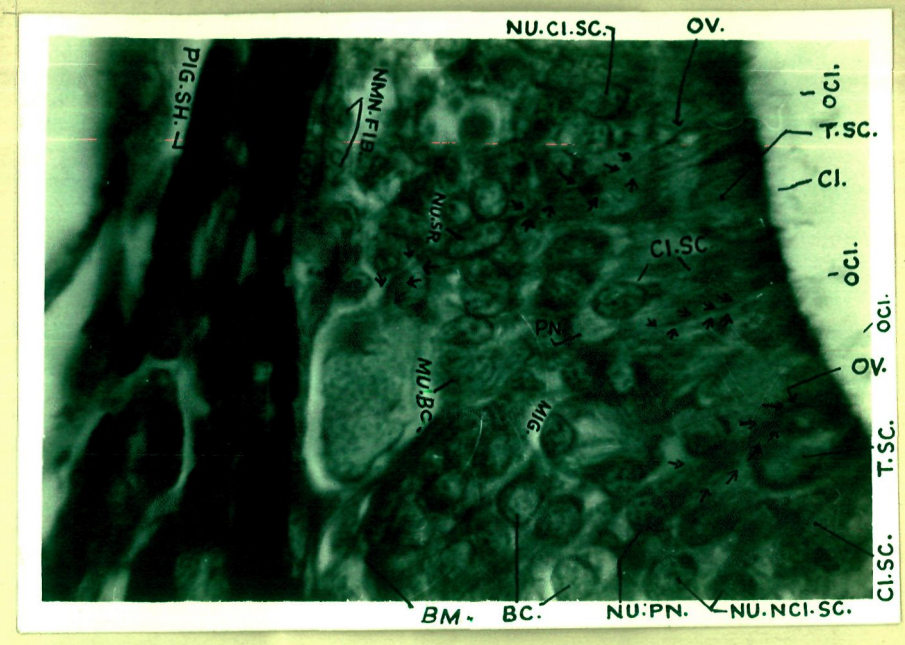

Fig. 93

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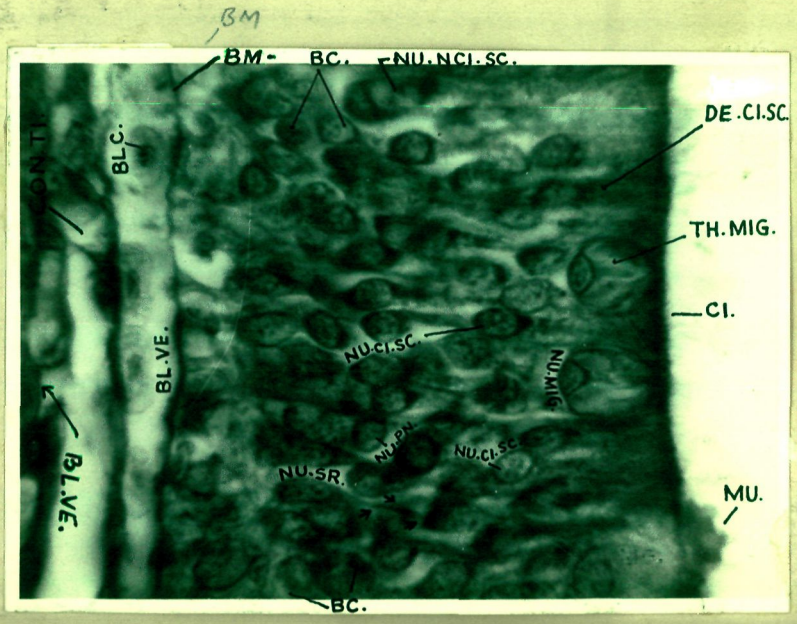

Fig. 94

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supplied by two blood capillaries (BL. V., Figs. 91, 92, 94): one arterial branch and another veinous branch. The posterior nasal opening of the olfactory rosette is opened in the ventro-laterally situated infranasal chamber (INF. NAS. CHAM., Fig. 86B) which is made up of thin lining of flattened epithelial cells. It is supported by the cartilage.

The olfactory epithelium of M. armatus armatus is made up of a compact cellular components of mucosa (MSA.) which is separated by the central core or submucosa (SMSA.) by a well defined basement membrane (BM.). The mucosa (MSA.) consists of cuboidal and ciliated epithelium. The olfactory epithelium consists of the following cell types: the supporting cells, the receptor cells, the goblet cells and the basal cells.

The supporting cells:

The supporting cells (CI. SC., Figs. 91, 92, 93, 94, 96) are arranged compactly in two successive rows in the olfactory epithelium and allow the passage of dendrites of receptor cells to its peripheral or distal surface. The nuclei (NU. CI. SC., Figs. 93, 94) of these cells have delicate out line with clearly visible nucleolus and chromatin material. The supporting cells are provided with short and thick distal limb (DL. CI. SC.) which ends on the peripheral surface by a convex end. The distal limb is filled with granular cytoplasm and granulation is more concentrated towards the convex end which bear cilia projecting into the interlamellar spaces.

The row of supporting cells lying extreme distally with ciliated convex end can be demarcated as secondary supporting cells and second row of nonciliated cell (NCI. SC., Figs. 93, 94, 95) can be called as primary supporting cells. The latter type of cells may either be transformed in the secondary supporting ciliated cells or in mucous secretary goblet (T. SC., Fig. 95) cells and their transitionary stages can be observed. The nonciliated supporting cells can also be confused with the basal cells.

The receptor cells:

They are abundantly supplied in the olfactory epithelium of A. armatus armatus lying at its different depths. They can be distinguished in two types: (1) The primary neurones and (2) The spindle shaped receptor cells.

The primary neurones are richly concentrated in distal and proximal regions of the lamella (PN., Figs. 93, 95) although their rare occurrence can be noticed any where in the olfactory epithelium (PN., Fig. 94). They can be identified by a rounded darkly staining nuclei (NU. PN., Figs. 93, 94, 95), which send fine cylindorical dendritic (DN. PN.) process to the distal surface of the olfactory epithelium. The axonal end (AX. PN., Fig. 95) of these cells is short and hardly traceable but, however, at some places a clear axon can be seen which joins collectively to form follium olfactorium. The primary neurones

Fig. 95. Transverse section of lamella of *M. armatus armatus* passing through the distal tip of lamella which solely occupied by primary neurone. Arrows indicate the pathways of axon. Magnification X 1000.

AX. PN.	Axon of primary neurone
BC.	Basal cell
BL. VE.	Blood vessel
DE. LAM.	Distal tip of lamella
DN. PN.	Dendrite of primary neurone
FI. OL.	Folium olfactorium
NU. PN.	Nucleus of primary neurone
OCI.	Olfactory cilia
PN.	Primary neurone

Fig. 96. Transverse section of lamella of *M. armatus armatus* passing through the thicker regions of lamella where spindle shaped receptor cells lie deep in the olfactory epithelium sending correspondingly elongated dendrites. Olfactory vesicle and olfactory cilia are visible. Arrows indicate the pathways of dendrites. Magnification X 1000.

BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
CI. SC.	Ciliated supporting cell
FI. OL.	Folium Olfactorium
NMN. FIB.	Nonmedullated nerve fibre bundle
NU. NCI. SC.	Nucleus of nonciliated supporting cell
NU. SR.	Nucleus of spindle shaped receptor cell
OV.	Olfactory vesicle
PN.	Primary neurone
SR.	Spindle shaped receptor cell.

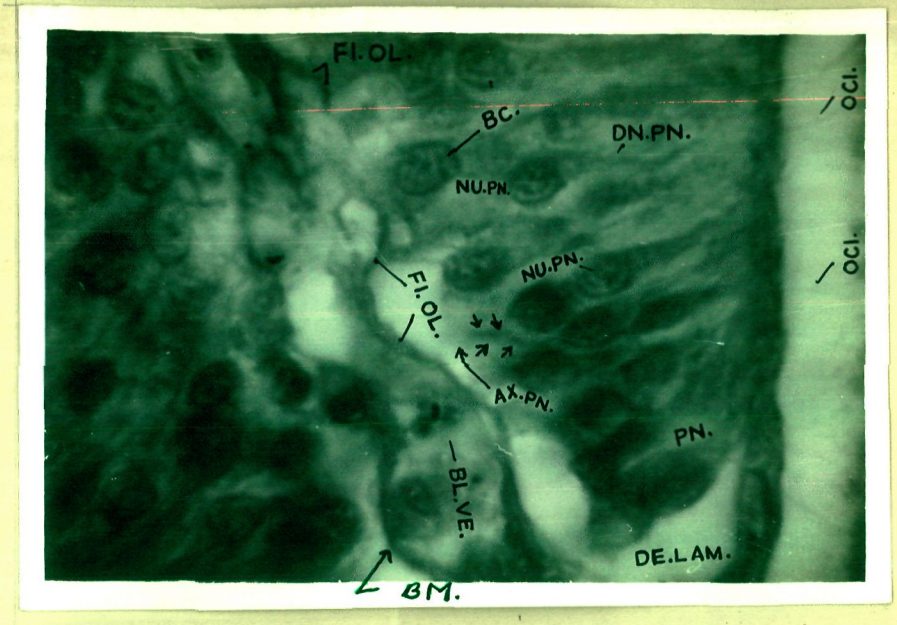

Fig. 95

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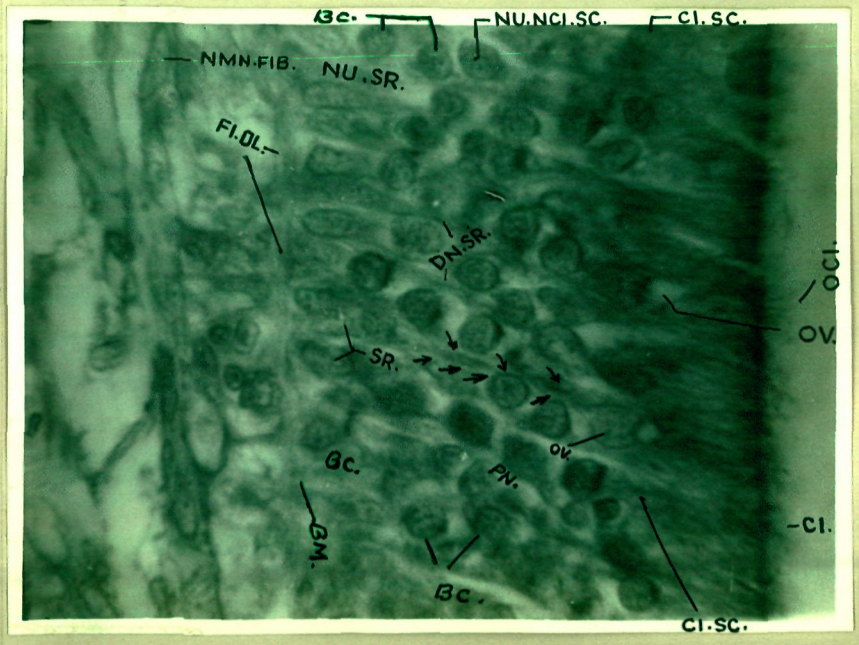

Fig. 96

~~94~~ 96

are the independent cellular organization and never form synaptic contact with other neurones. The dendrites bear olfactory cilia (OCI., Figs. 93, 95) which project into interlamellar spaces.

The spindle shaped receptor cells (SR.) are present in the thicker regions of the olfactory epithelium. They have their elongated nuclear body (NU. SR.) in the deeper regions of the olfactory epithelium and send the dendrites to its distal or peripheral region which end in the form of an olfactory vesicle. The olfactory vesicle (V., Figs. 93, 96) lies embedded in the distal supporting zone and gives rise to dense olfactory cilia (OCI., Figs. 93, 95, 96) projecting in the interlamellar spaces. The nuclear body of the secondary receptor cells lies very close to basement membrane and short axon (AX. SR., Figs. 93, 96) meet proximally to form follium olfactorium (FI. OL., Figs. 93, 94, 95, 96) which extends along the basement membrane and ultimately joins nonmedullated fibres at proximal region of each lamella (Figs. 93, 94, 95, 96).

The mucous secretory goblet cells:

The goblet cells (MIG.) are richly distributed in the olfactory epithelium of M. armatus armatus but they are seen in each lamella. The rich occurrence of goblet cells can be noticed in the distal end of the lamellae. The goblet cells are of wine cup like in structure having swollen ovoid theca

(TH. MIG.) with nuclear (NU. MIG.) and cytoplasmic content pushed proximally in the form of a triangular mass. The chromatin material and nucleolus are not visible due to the high degree of compression. The goblet cells of the olfactory epithelium of M. armatus armatus are characterised by a beak which project into the interlamellar space. Such beaked goblet cells are rarely encountered in the olfactory epithelium of C. carpio but are commonly present in the olfactory epithelium of M. armatus armatus. (MIG., Figs. 91, 92, 93, 94). They may be transformed either by primary supporting cells or by basal cell, therefore, their formative stages can be seen in the basal or primary supporting zones. The migratory tendency (MIG., Figs. 93, 94) is observed which brought them upto the peripheral surface where mucous is discharged into the interlamellar spaces (Figs. 91,92,93,94).

The basal cells:

The basal cells form a three to four layers thick basal zone just above the basement membrane. They are aggregated in the proximal intervening regions, adjacent to the floor of the lamellae. The basal cells are the smallest cellular component of the olfactory epithelium. They may be rounded or oval in shape with darkly staining nuclei and clearly visible nucleolus and chromatin material. Some of the basal cells are positively muciperous and give rise to the mucous secretory goblet cells. The basal cells are the mother cells of all other cellular

component of the olfactory epithelium and some stages of mitotic division can be observed in them. Their first transformed form is primary supporting cells which ultimately get transformed into secondary supporting cells (Figs. 91, 92, 93, 94, 95, 96).

The central core or submucosa:

The central core or submucosa of the lamella is separated from the receptor layer on either sides by the basement membrane. It is filled with dense connective tissue (CON. TI., Figs. 91, 92, 94) of collagen and reticuline fibres. The connective tissue of the central core of the lamella is in continuation of the connective tissue lying in the periphery of the rosette. The matrix is dense compactly cementing the connective tissue fibres. The pigment cells are confined in the connective tissue all around the periphery of the rosette not in the submucosa of the lamellae. The central core or submucosa of all the lamellae is supplied by blood vessels of orbitonasal artery and vein. In this way two blood capillaries are seen in the submucosa of each lamellae (Figs. 91, 92, 94).

The accessory nasal sac:

It is made up of cuboidal epithelium (CU. SC.) and richly supplied with rounded goblet cells (GC.). The internal lining of the sac possesses hillock elevation (HIL. ELE.) and depressions which becomes more prominent to the posterior side (Figs. 97,100).

Fig. 97. Horizontal section of the anterior nasal tube and anterior accessory nasal sac of *A. armatus* armatus showing deposition of mud and other foreign particles. Arrows indicate the way to the lumen of rosette. Magnification X 100.

ANT. ACC. NAS. SAC.	Anterior accessory nasal sac.
ANT. NAS. OP.	Anterior nasal opening
ANT. NAS. TEN.	Anterior nasal tenticle
ANT. NAS. TUBE	Anterior nasal tube
INTEG.	Integument
MUD	Mud and foreign particles

Fig. 98. Magnified photograph of the olfactory rosette of *A. notopterus* showing lamellar arrangement on the either side of raphe and linguiform processes.

ANT.	Anterior
INT. LAM. SP.	Interlamellar space
LAM.	Lamella
LING.	Linguiform process
PIG.	Pigmentation
POST.	Posterior
RPH.	Raphe
VEN. SUR.	Ventral surface

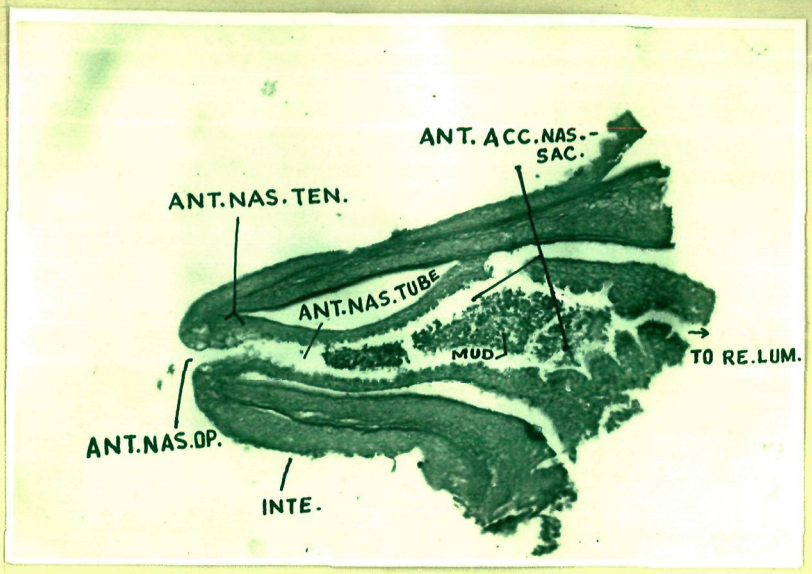

Fig. 97

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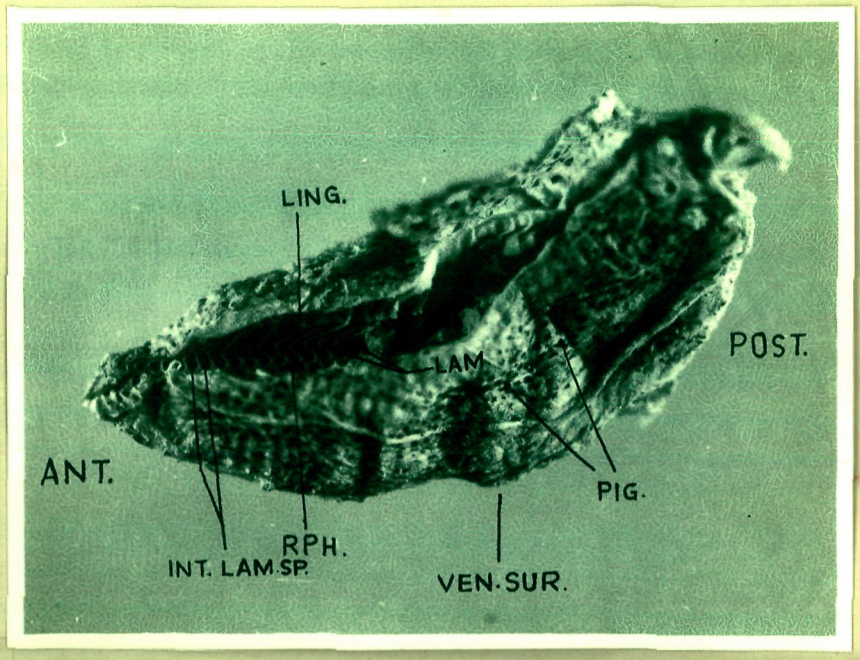


Fig. 98

98

Fig. 99. Horizontal section passing through the anterior nasal tube and anterior accessory nasal sac of M. armatus armatus showing all processes and cuboidal supporting cell. Magnification X 400.

ANT. ACC. NAS.SAC.	Anterior accessory nasal sac
ANT. NAS. TUBE	Anterior nasal tube
BC.	Basal cell
CON. TI.	Connective tissue
CU. SC.	Cuboidal supporting cell
C. PRO.	Cell processes

Fig. 100. Horizontal section passing through the anterior accessory nasal sac,of M. armatus armatus showing hillock elevations, goblet cells, cuboidal supporting cells and deposition of mud and foreign particles. Magnification X 400.

BC.	Basal cell
CU. SC.	Cuboidal supporting cell
GC.	Goblet cell
HIL. ELE.	Hillock elevation
TO.RE. LUM.	Passage to the lumen of the rosette.

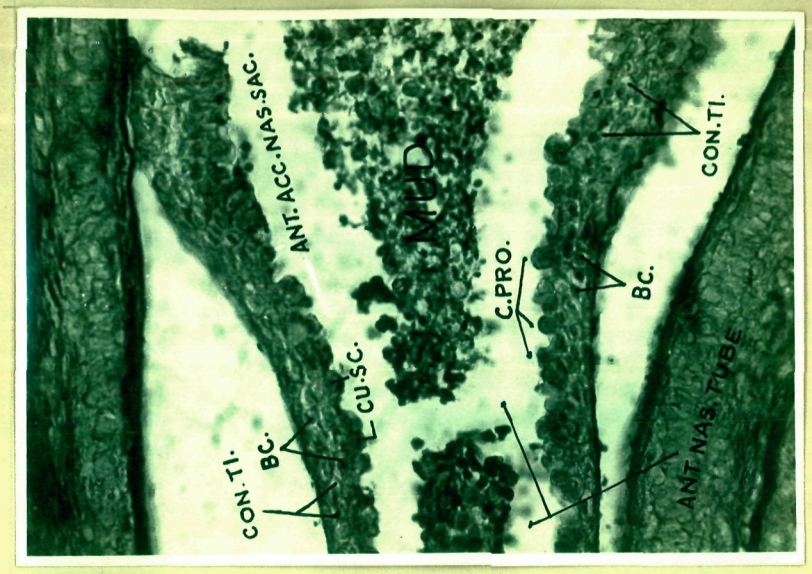


Fig. 99

94

Fig. 100

100

The outer or peripheral lining of the sac is constituted of cuboidal supporting cells with intervening mucous secretory goblet cells and inner or proximal region is filled with basal cells (BC.) and connective tissue (CON. TI.) fibres. The anterior nasal tube is lined with nonciliated cuboidal supporting cells but provided with cell processes (C. PRO., Fig. 99). The mud and other foreign materials (MUD) are intengled in the mucous from the water passing through the nasal sac and mud-free water is allowed to the lumen of rosette. This is an additional device to this mud dwelling fish (Figs. 97, 100). The mud and other foreign particles (Figs.97, 99, 100) deposited in the sac is removed by reverse water current which is created by the compression of infranasal chamber (INF. NAS. CHAM., Fig. 868) and closing of posterior nasal opening.

ANATOMICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *ESOMUS DENRICUS* (HAMILTON-BUCHANAN)

The olfactory organs of *E. danricus* consist of a paired olfactory chambers situated on the dorso-lateral surface of the snout, mesial to the maxillary barbels, anterior to and almost at the same level of the eyes (Figs. 101, 103A). Each chamber opens outside by a pair of openings which are termed as anterior and posterior nasal openings (ANT. NAS. OP. AND POST. NAS. OP., Figs. 101, 103A, 103B). The anterior opening is borne on an outwardly and forwardly directed short tube (ANT. NAS. TUBE, Figs. 101, 103A, 103B). The posterior opening is been shaped flush with the surface of skin. The two openings are closely placed to one another. The posterior wall of the anterior tubular opening is the only partition visible in between both the openings. A very small part of the anterior portion of the rosette peeps through the anterior tubular opening, while major part of its posterior portion can be seen through the posterior opening. Chromatophores are observed through out the skin of the fish. Even a few chromatophores are also present on the anterior tube (Figs. 100, 103A, 103B).

The olfactory chamber lies more closer to the eyes as compared to the margin of the snout. In a fish of total length 60 mm the chamber is placed at a distance of 0.234 mm from eye orbit and 0.819 mm from the margin of the snout. The length of

Fig. 101. Lateral view of the head of E. denricus.

ANT. NAS. OP.	Anterior nasal opening
ANT. NAS. TUBE.	Anterior nasal tube
POST. NAS. OP.	Posterior nasal opening

Fig. 102. Dissection of the head from lateral side to show the rosette in situ. of E. denricus.

LAM.	Lamella
RPH.	Raphe
W. OLF. CHAM.	Wall of olfactory chamber

POST. NAS. OP.
ANT. NAS. TUBE
ANT. NAS. OP.

Fig. 101

101

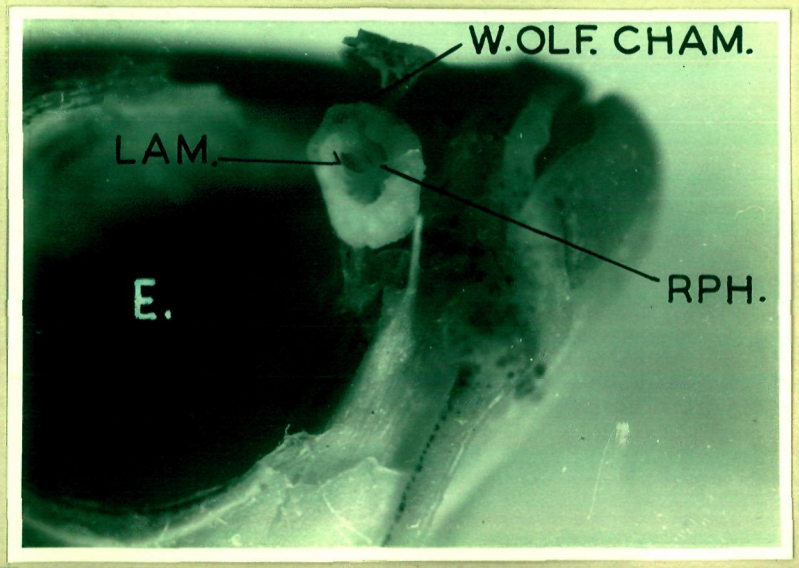


Fig. 102

102

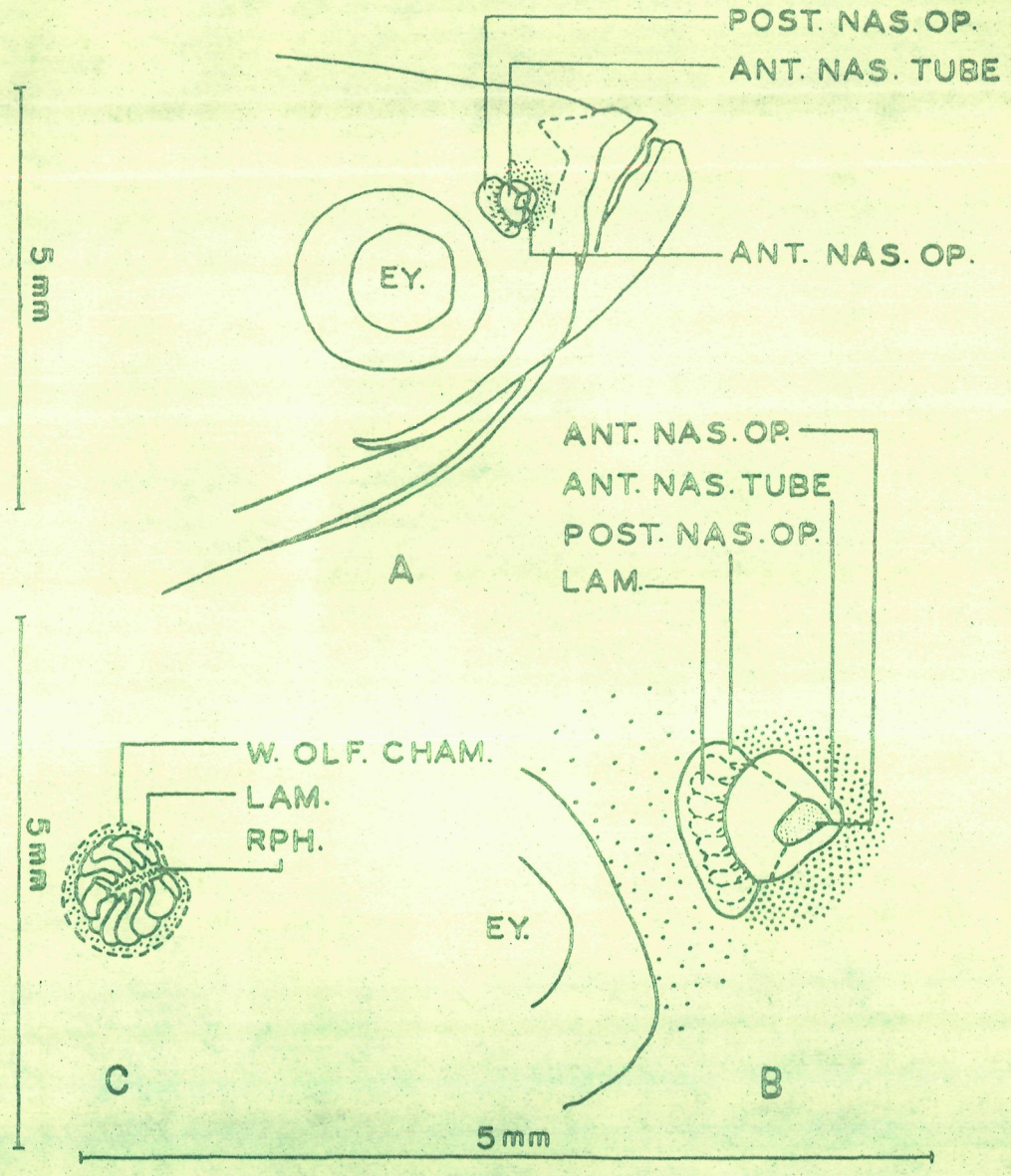
Fig. 103A. Diagram of the lateral view of the head of *E. denricus*.

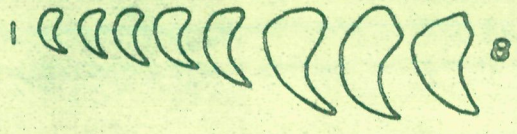
Fig. 103B. Diagram of the olfactory chamber with two openings and anterior nasal tube.of *E. denricus*.

Fig. 103C. Diagrammatic sketch of the rosette of *E. denricus*.

Fig. 103D. A set of 1-8 lamellae from one half of the rosette of *E. denricus*.

ANT. NAS. OP.	Anterior nasal opening
ANT. NAS. TUBE.	Anterior nasal tube
EY.	Eye
LAM.	Lamella
POST. NAS. OP.	Posterior nasal opening
RPH.	Raphe
W. OLF. CHAM.	Wall of olfactory chamber


POST. NAS. OP.
ANT. NAS. TUBE
ANT. NAS. OP.
EY.
5 mm
A
ANT. NAS. OP.
ANT. NAS. TUBE
POST. NAS. OP.
LAM.
W. OLF. CHAM.
LAM.
RPH.
5 mm
EY.
C
B
5 mm


1
8

5 mm

D

FIG. 103.

the posterior nostril is 0.585 mm and width 0.234 mm. Both the openings are placed at a distance of 0.351 mm. The length of the anterior tube is found to be 0.585 mm.

An almost rounded olfactory chamber is lodged in the fossa of the ethmoidal region of the skull and is attached to the surrounding cranial bones by fibrous connective tissue. Each chamber contains rounded rosette which occupies almost whole of its entire cavity. The longitudinal axis of the rosette is oriented obliquely in relation to the median axis of the body of fish.

The olfactory rosette is oval-bowel shaped (Figs. 102, 103C). It possesses a dorsal concave and a ventral convex surface. On the dorsal concave surface of the rosette lies a thick and prominent raphe (RPH.). This is formed due to infolding of the wall of the olfactory epithelium. It remains in an uniform dimension through out its length and allows the attachment of lamellae on its either sides (Figs. 102, 103C, 106, 107).

The olfactory lamellae (LAM.) are arranged on either sides of the raphe. The ventral part of the lamella is attached to the wall of the olfactory chamber, while proximally with the raphe. Each lamella is swollen and flattened in structure. The lamellae are devoid of linguiform processes. The lamellae are present at the anterior and posterior parts of the rosette which

Fig. 104. Diagram of the lateral view of the skull of *A. americus*.

DEN.	Dentary
DSPH.	Dermasphenoid
ETH.	Ethmoid
FRON.	Frontal
HYO.	Hyomandibular
IOPR.	Interoperculum
LAC.	Lacrymal
LETH.	Lateral ethmoid
MAX.	Maxilla
MPT.	Metapterygoid
NAS.	Nasal
OPR.	Operculum
ORBSPH.	Orbitosphenoid
PAL.	Palatine
PAS.	Parasphenoid
PREMAX.	Premaxilla
PREOPR.	Preoperculum
Q.	Quadrate
SOPR.	Suboperculum
SYM.	Symplectic

(Posterior region is not drawn) 2,3,4,5, circumorbitals.

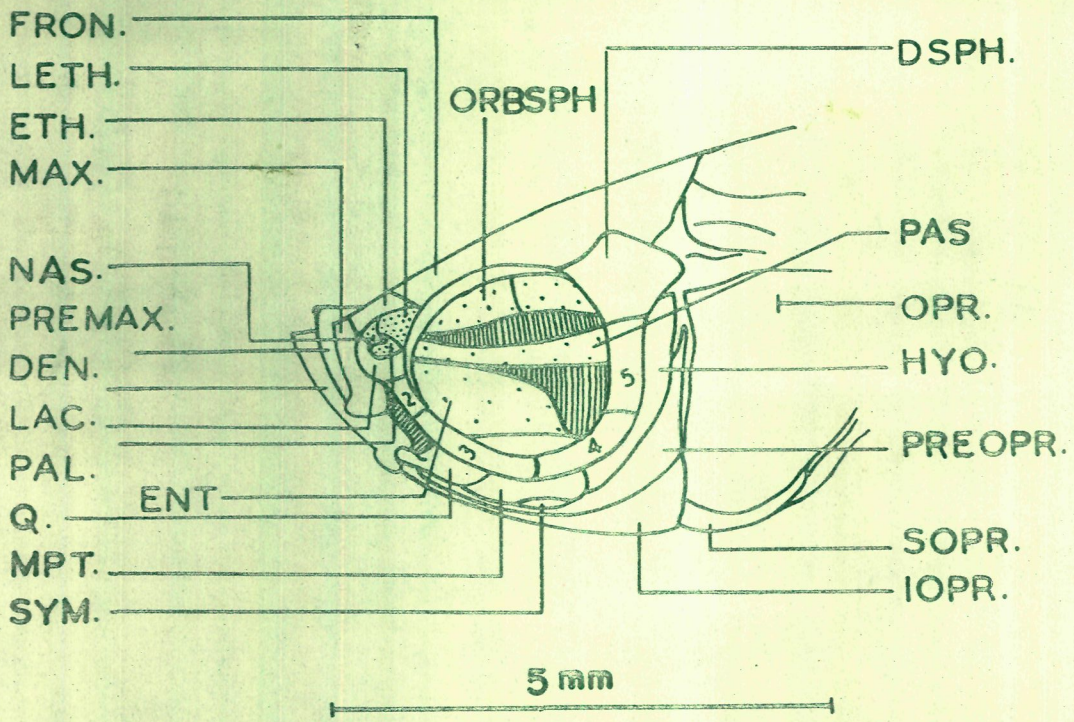

FRON.
LETH.
ETH.
MAX.
NAS.
PREMAX.
DEN.
LAC.
PAL.
ENT
Q.
MPT.
SYM.
ORBSPH
DSPH.
PAS
OPR.
HYO.
PREOPR.
SOPR.
IOPR.
1
2
3
4
5
5 mm

FIG.104.

Fig. 105. Diagram of the dissection of *S. denricum* from dorsal side to show the relationship of brain with the rosette.

CE.	Cerebellum
EY.	Eye
OLF. BL.	Olfactory bulb
OLF. LO.	Olfactory lobe
OLF. NE.	Olfactory nerve
OLF. TR.	Olfactory tract
OP. LO.	Optic Lobe
RE.	Rosette

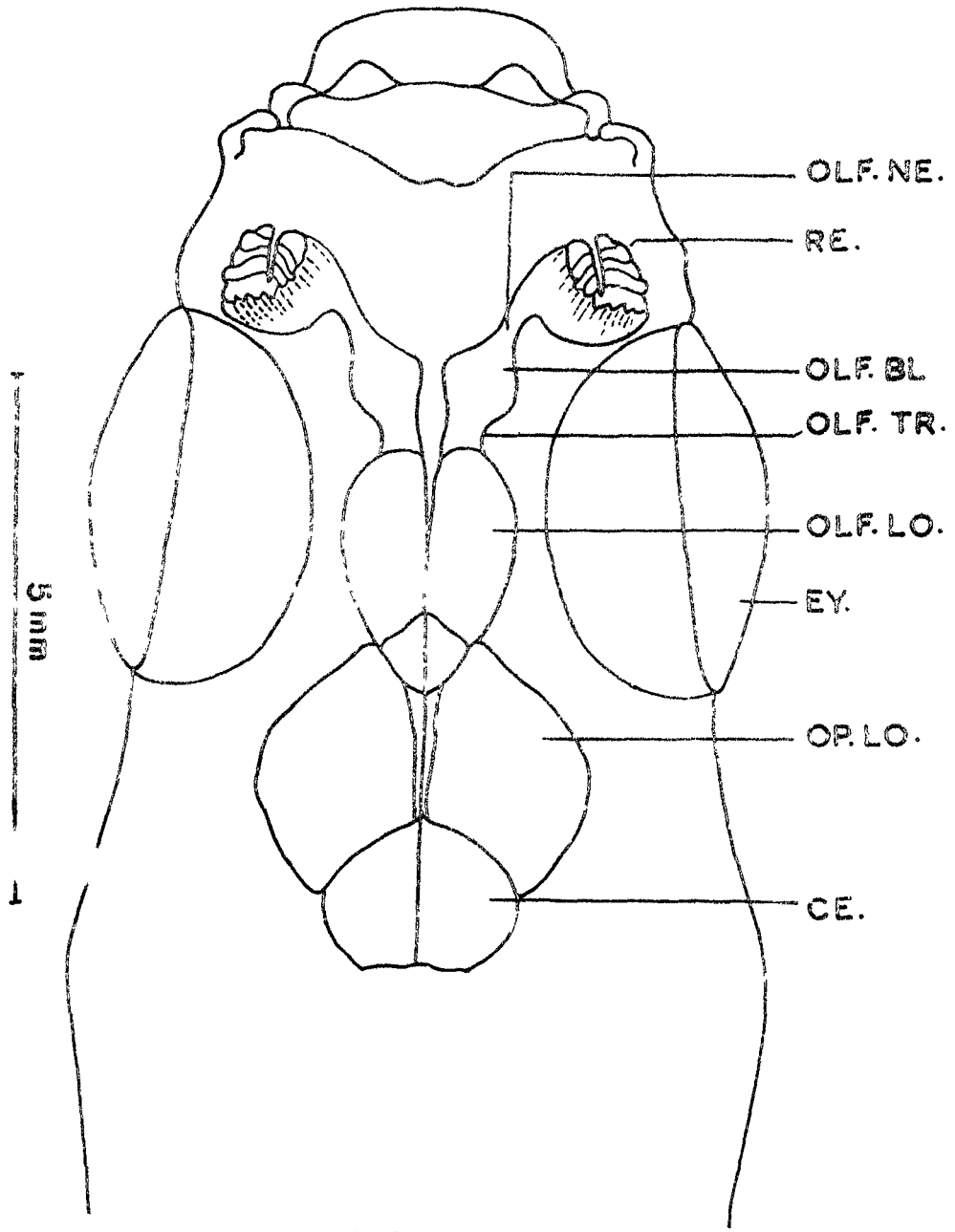


FIG. 105.

are attached obliquely to the raphe, while the middle ones are almost perpendicular to it. The lamellae of the anterior portion of the rosette project upwards and those of the posterior faces downwards (Figs. 102, 103C). The lamellae are closely placed to one another. The interlamellar spaces (INT. LAM. SP.) are visible.

The smallest lamella is observed at the anterior most part of the rosette. This indicates that the addition of new lamellae takes place at this end. The size of lamellae gradually increases towards the posterior (4-8 lamellae of one half of the rosette).

The olfactory chamber is cup shaped and lies in fossa formed by number of bony components. The fronto-ethmo-premaxillary complex forms the boundary of olfactory chamber. The floor of the chamber is scooped on the palatine (PAL.) in the form of cuplike structure which is surrounded by lateral ethmoid (LETH.). It is partially guarded postero-dorsally by frontal (FRON.); antero-laterally by the maxilla (MAX),premaxilla (PREMAX.),and ventro-laterally by the lacrymal (LAC.). Antero-dorsally the lateral wing of the median ethmoid (ETH.) protects the olfactory chamber and forms internasal septum which along with its cartilage encircles the anterior tube of nasal opening. A foramen for the passage of the olfactory nerve is present at the union point of the median ethmoid and ethmoid in the posterior region of olfactory chamber (Fig. 104).

Table 5 : Paoma denricus (Eye-fish)

S.No.	Total length	No. of lamellae on Rosette		Total length of the Brain	Length of Diencephalon	Length of Telencephalon	Ecological coefficient (Through lobes of Brain) Length of Telencephalon X 100 / Length of Diencephalon	Retinal area of both eyes	Olfactory area of both rosette	Ecological coefficient (Through area) Olfactory area X 100 / Retinal area
		Right	Left							
1.	34 mm	11	10	2.87 mm	1.20 mm	1.05 mm	87.50	10.20 mm^2	6.02 mm^2	67.84
2.	45 mm	12	12	3.96 mm	1.30 mm	1.10 mm	84.61	14.12 mm^2	9.30 mm^2	65.86
3.	50 mm	12	13	4.28 mm	1.40 mm	1.24 mm	88.57	14.12 mm^2	10.24 mm^2	72.52
4.	60 mm	14	14	4.32 mm	1.61 mm	1.37 mm	86.33	22.46 mm^2	17.48 mm^2	77.82
5.	65 mm	16	17	4.44 mm	1.63 mm	1.44 mm	88.34	25.12 mm^2	20.32 mm^2	80.89

After dissecting the fish from dorsal side and removing the frontal and ethmoid bones the anatomical relationship of brain with the olfactory organs is clearly exposed. From the olfactory rosette arises olfactory nerve (OLF. NE.) which passes through the foramen and joins to the olfactory bulb (OLF. BL.) lying in between the olfactory lobe (OLF. LO.) and olfactory rosette. The bulb is connected to the fore brain by a thick olfactory tract (OLF. TR.). The brain lies just behind the eye orbit in the dorsal position of the skull. The optic bulbs (OPT. LO.) are well developed. The olfactory lobes are comparatively less developed. The presence of olfactory bulb in between the telencephalon and olfactory rosette is a rare feature and is observed in E. denricus (Fig. 105). The length of brain and its components show a successive increase in the length with respect to the size of the fish (Table 5).

Ecological co-efficient:

The parameters of length of telencephalon, mesencephalon, area of two retinae and both the rosettes are taken into the consideration for determining the ecological co-efficient of olfactory and optic faculties.

Five fishes of different sizes ranging from 34 mm to 65 mm are selected for calculating the aforesaid factor. It was found that the length of the mesencephalon (OP. LO.) ranges from 1.20 mm to 1.63 mm while that of telecephalon (OLF. LO.) from

1.05 mm to 1.44 mm. The area of two retinae and both rosettes are measured, and former ranges from 10.20 mm^2 to 25.12 mm^2 while latter from 6.92 mm^2 to 20.32 mm^2 (Table 5).

E. denricus shows feebly developed olfactory faculty because optic centre in the brain as well as the area of two retinae are more developed as compared to the telencephalon and the area of both the rosettes. This reveals that the fish under study is an "Eye fish" with predominantly developed optic faculty which helps in locating the food material and recognizing the fright reaction etc.

The route of circulation of water current through the olfactory chamber of E. denricus:

The rapid protrusion and retraction of jaws along with antero-posterior beating of the long tuft of cilia (CI., Figs. 109, 110, 111, 112) of the lamella cause the entry of water current into the olfactory chamber through forwardly projected anterior nasal tube (ANT. NAS. TUBE, Figs. 103A, 103B). E. denricus is always found moving rapidly in natural habitat with continuously protruding and retracting the jaws. This feature allows easy and regular flow of water into the olfactory chamber. The wide posterior nasal opening of E. denricus is kept under a constant touch of water with olfactory rosette even in stationary condition of the fish (Fig. 103B).

The route of transportation of water in *E. dentriens* is shortest as compared to *C. carpio*, *H. fossilis*, *N. notopterus* and *A. armatus armatus* because most of the olfactory chamber is exposed to water through the wide posterior nasal opening.

Fig. 106. Horizontal sections of the rosette of E. denricus showing the attachment of lamellae on its either side. Magnification X 100.

INT. LAM. SP.	Interlamellar space
LAM.	Lamella
MSA.	Mucosa
RPH.	Raphe
SMSA.	Submucosa
W. OLF. CHAM.	Wall of olfactory chamber

Fig. 107. Horizontal section of rosette of E. denricus passing through the raphe showing its sensory and ciliated nature. Magnification X 400.

BC.	Basal cell
BM.	Basement membrane
CI.	Cilia
CON. TI.	Connective tissue
CON. TI. FI.	Connective tissue fibres
DPN.	Depression
FB. C.	Fibre-blast cell
FI. OL.	Folium olfactorium
NMN. FIB.	Non-medullated nerve fibre bundle
OCI.	Olfactory cilia
SR.	Spindle shaped receptor cell

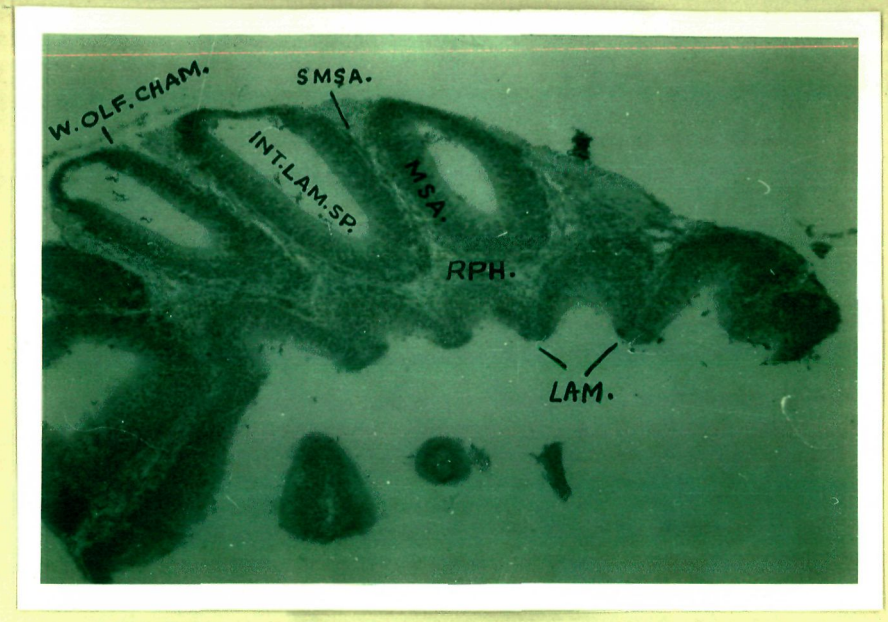


Fig. 106

106

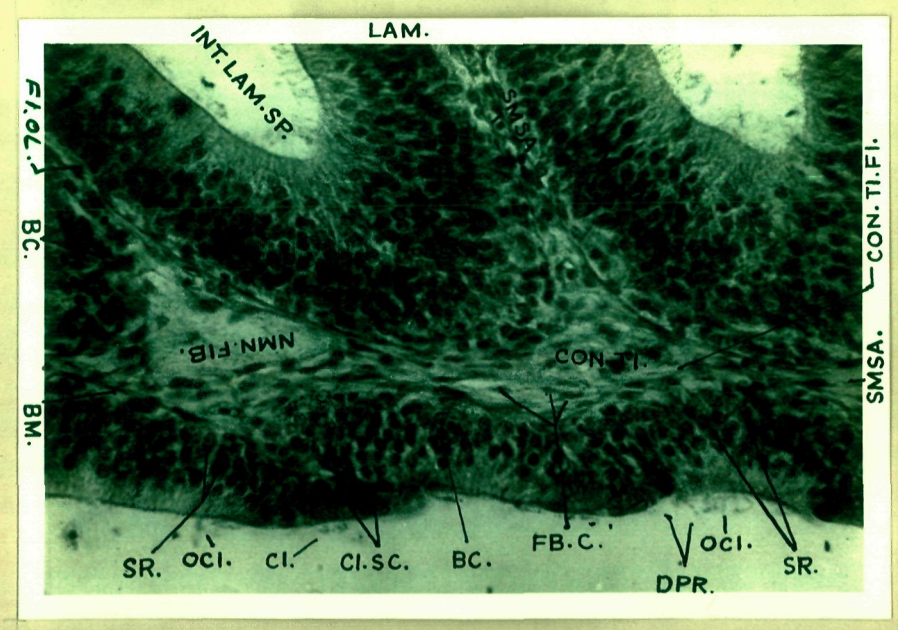


Fig. 107

107

Fig. 108. Transverse section of the rosette of *H. denricus* passing through two lamellae. Magnification X 100.

ARE.	Areolae
COL. FIB.	Collagen fibre bundle
DE. LAM.	Distal end of lamellae
G.	Goblet cell
LYM. SP.	Lymphatic space
MSA.	Mucosa
PR. LAM.	Proximal end of lamella
PROT.	Protuberance
RPH.	Raphe
SMSA	Submucosa

Fig. 109. Vertical section of lamella of *H. denricus* showing faint elevations and depressions on the free surface with alternating series of smaller and larger (olfactory cilia) cilia. Magnification X 400.

BCP.	Blood capillary
BM	Basement membrane
CI.	Cilia
DPR.	Depression
ELE.	Elevation
FI. OL.	Folium olfactorium
INT. LAM. SP.	Interlamellar space
NMN. FIB.	Non-medullated nerve fibre bundle
OCI.	Olfactory cilia

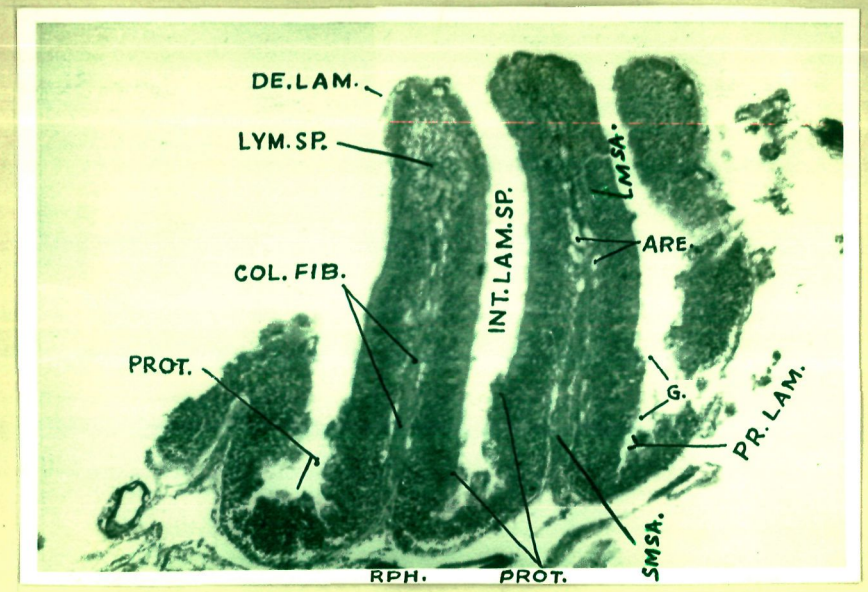


Fig. 108

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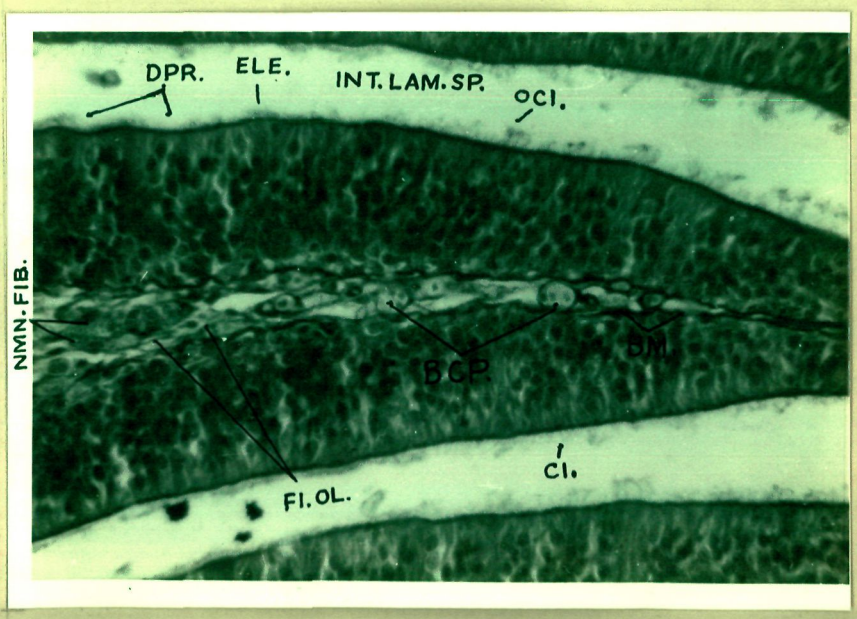

Fig. 109

109

HISTOLOGICAL OBSERVATIONS OF THE OLFACTORY ORGAN OF *ESOMUS DENRICUS* (HAMILTON-BUCHANAN)

The olfactory rosette of *Esomus danricus* bears ten to fourteen lamellae, attached on either sides of raphe. The radial lamellae arise by relatively narrow blade like stem from the olfactory chamber. Each lamella comprises of a central core or submucosa (SMSA.) which is lined on both the sides by a sensory epithelium or mucosa (MSA., Figs. 108, 113). A prominent basement membrane (BM.) demarcates the central core with the epithelial lining. The surface of the lamellae gives faint impression of depressions (DPR.) and elevations (ELE.) which are alternately lined by the smaller and longer cilia (CI. AND OCI., Figs. 109, 110, 111). The former are the cilia of supporting cells while latter are olfactory cilia arising from the terminal tips of the dendrites of receptor cells. In the distal end of the lamella the elevations and depressions are well marked and bear dense ciliation. In the proximal regions of some lamellae a cellular activity is noticed resulting the formation of protuberans (PROT., Figs. 108, 113) like structure. The formation of secondary lamellae or other microformations are not observed on the peripheral surface of the olfactory epithelium. The central core is quite spacious on the proximal end but narrows gradually towards the distal extremity. It has dense areolar connective tissue which forms turgor for providing the

strength to the lamellae. The vascular and nervous supply extend through the central core or submucosa. The nonmedullated nerve (NMN. FI.) fibres extending through the central core or submucosa which join with the medullated nerve fibres in the rache.

The olfactory epithelium of H. denricus comprises of the supporting cells, the receptor cells, the basal cells and the mucous secretory goblet cells.

The supporting cells:

The supporting cells can be identified by their prominent nuclei in which chromatin material and nucleolus are clearly visible. They are of two types: ciliated and nonciliated supporting cells. The ciliated supporting cells (CI. SC.) have broad and columnar distal limb, extending upto the free or superficial surface where it ends by an expanded tip. The cilia are planted on the basal granules lying on the terminal tip of columnar cell and projected into the interlamellar spaces in the form of small cilia. The nuclei of ciliated supporting cells (NU. CI. SC.) have a delicate out line and take dark stain of haematoxylin. The proximal limb of ciliated supporting cells is not traceable due to the dense cellular contents beneath them (Figs. 110, 111, 112).

The nonciliated supporting cells (NCI. SC.) are also observed in olfactory epithelium of H. denricus but they are

Fig. 110. Transverse section of lamella of *H. denricus* showing uniformly present spindle shaped receptor cells in the deeper region of mucosa sending elongated and thick dendrite which end into olfactory vesicle. Primary nurones are also supplied with their distinct dendritic processes. Arrows indicate the pathway of axon. Magnification X 600.

AX. SR.	Axon of spindle shaped receptor cell
BC.	Basal cell
BCP.	Blood capillary
BM.	Basement membrane
CI.	Cilia
CI. SC.	Ciliated supporting cell
DN. PN.	Dendrite of primary neurone
DN. SR.	Dendrite of spindle shaped receptor cell
FI. OL.	Folium olfactorium
INT. LAM. SP.	Interlamellar space
NCI. SC.	Non ciliated supporting cells
NU. CI. SC.	Nucleus of ciliated supporting cells
NU. NCI. SC.	Nucleus of non-ciliated supporting cells
NU. PN.	Nucleus of primary neurone
NU. SR.	Nucleus of spindle shaped receptor cells
OCI.	Olfactory cilia
OV.	Olfactory vesicle

Fig. 111. Transverse section of the lamella of *H. denricus* showing antenna like olfactory cilia projected into the interlamellar spaces. Magnification X 1000.

AX. SR.	Axon of spindle shaped receptor cell.
BC.	Basal cell
CI. SC.	Ciliated supporting cell
FB. C.	Fibroblast cell
FI. OL.	Folium olfactorium
NU. CI. SC.	Nucleus of ciliated supporting cell
NU. SC.	Nucleus of supporting cell
OCI.	Olfactory cilia
PN.	Primary neurone
SMSA	Submucosa
SR.	Spindle shaped receptor cell

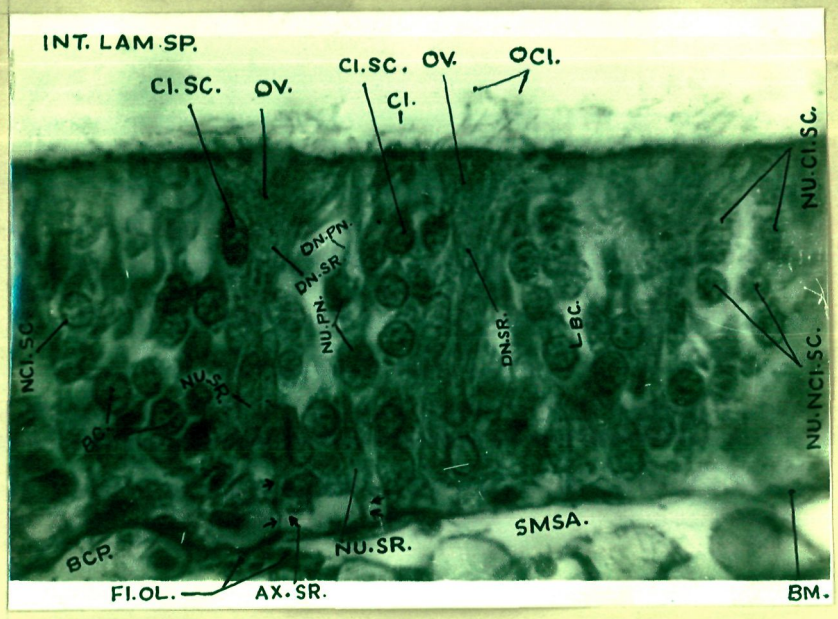

Fig. 110

110

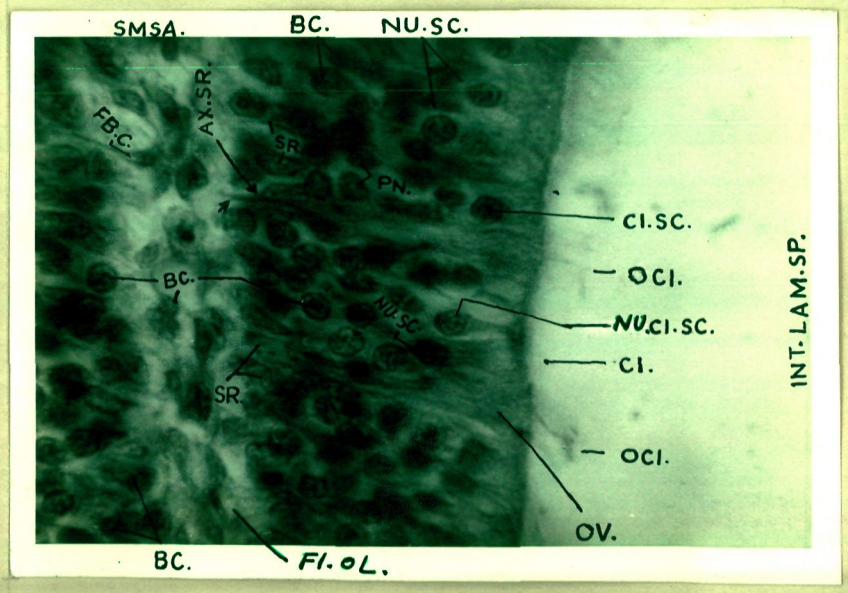

Fig. 111

111

rarely present near the ciliated supporting cells. The nonciliated supporting cells are provided with almost spherical nucleus (NU. NCI. SC.) with a clearly visible nucleolus and chromatin material. The distal limb of these supporting cells is narrow and granulation is more prominent towards its tip. The nuclei of these cells are placed more peripheral in the olfactory epithelium (Figs. 110, 111, 112).

Both of the above supporting cells are not very compactly arranged and intercellular spaces can be seen in between them. The supporting cells are invariably alternated by the dendrite of receptor cells. The cilia (CI., Figs. 109, 110, 111, 112) of supporting cells project into the interlamellar spaces and their synchronous beating create the water current through the olfactory chamber.

The receptor cells:

The receptor cells can be identified as: the primary neurones and the spindle shaped receptor cells.

The primary neurones are distinguished by the darkly stained, rounded nuclei (NU. PN.) which generally lie below the nuclei of supporting cells. The thin dendrites (DN. PN.) of the primary neurone reach upto the free epithelial surface. Obviously dendrites of varying lengths, depending upon the depth of the neurone, can be observed in the olfactory epithelium of

E. denricus. The primary neurones (PN.) are distributed rarely and can be observed any where in olfactory epithelium. They never form aggregations of dendrites and olfactory cilia (OCI., Figs. 109, 110, 111, 112) are projected from their tip into the interlamellar spaces. The number of axon (AX. PN.) of primary neurones extend proximally and join to form folium olfactorium (FI. OL.) which ultimately join nonmedullated nerve fibres (NMN. FI.) present in the central core (Figs. 110, 111, 112).

The spindle shaped receptor cells (SR.) are uniformly present in the deeper regions of the olfactory epithelium and are arranged alternately to the group of basal cells. The nuclei (NU. SR.) are elongated having clearly visible nucleolus and chromatin material. The spindle shaped receptor cells send their thick and elongated dendrites (DN. SR.) upto the free surface of the olfactory epithelium where they constitute a clear olfactory vesicle (OV.). The vesicle bears two to three long olfactory cilia (OCI.) projecting straight in the interlamellar space. The olfactory cilia (OCI.) form a uniform ciliation alternating to the smaller ciliation (CI., Figs. 109, 110, 11) of supporting cells. The short axon (AX. SR., Figs. 110, 111) of all the spindle shaped receptor cells immediately join to folium olfactorium (FI. OL, Figs. 107, 109, 110, 111, 112, 113) after coming out from the cell body. The dendrites of the spindle shaped receptor cells do not form synaptic contact with the axon of primary receptor and, therefore, both

Fig. 112. Transverse section of lamella of *S. denricus* passing through submucosa. Magnification X 600.

BC.	Basal cell
BCP.	Blood capillaries
CI.	Cilia
CON. TI.	Connective tissue
FI. OL.	Folium olfactorium
NU. CI. SC.	Nucleus of ciliated supporting cell
NU. NCI. SC.	Nucleus of nonciliated supporting cell
OCI.	Olfactory cilia
OV.	Olfactory vesicle
PN.	Primary neurone
SR.	Spindle shaped receptor cells

Fig. 113. Vertical section of the lamella of *S. denricus* passing through the proximal region and showing morphogenetic activity of basal cell. Magnification X 400.

BCP.	Blood capillaries
BM.	Basement membrane
CON. TI.	Connective tissue
DPR.	Depression
FI. OL.	Folium olfactorium
G.	Goblet cell
GR. BC.	Grouping of basal cells
GR. G.	Grouping of goblet cell
MOR. BC.	Morphogenetic activity of basal cell
MSA.	Mucosa
OCI.	Olfactory cilia
PROT.	Protuberance
SMSA.	Submucosa

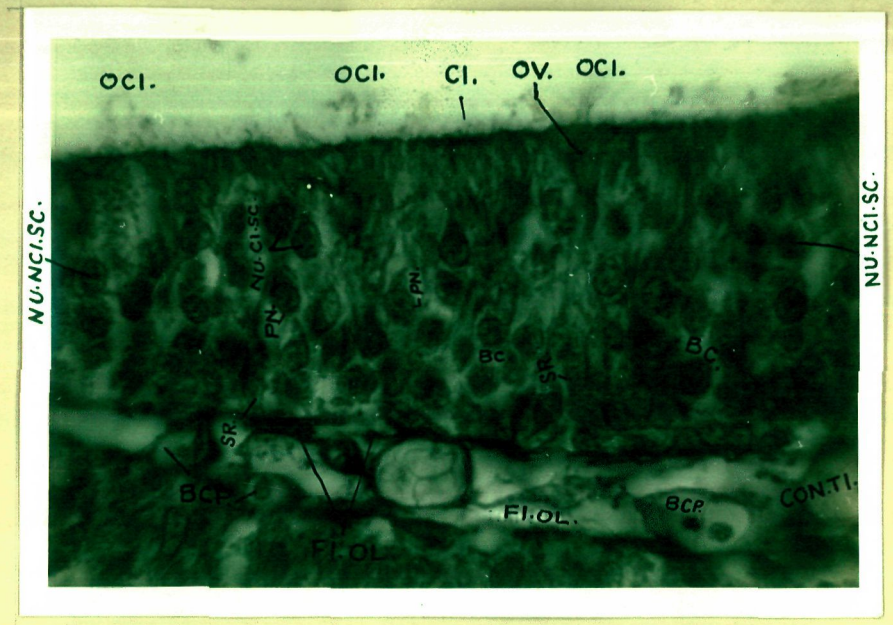

Fig. 112

112

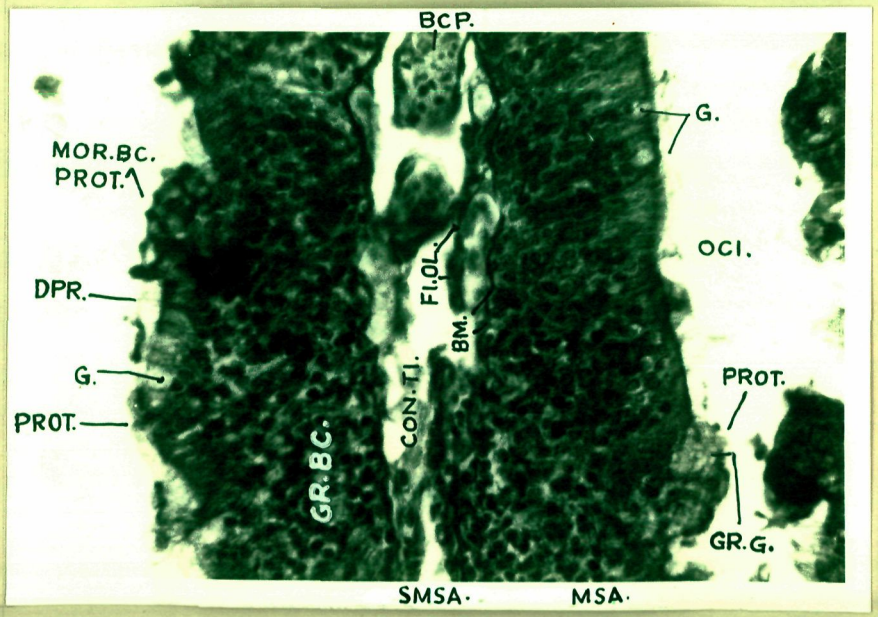

Fig. 113

113

the receptors maintain their independent identity. The spindle shaped receptor cells are richly and uniformly supplied in the olfactory epithelium of E. denricus in alternation to the supporting cells (Figs. 110, 111, 112).

The goblet cells:

These are rarely available cellular contents of the olfactory epithelium of E. denricus and are confined in the proximal regions of the lamella. The goblet cells (G.) are small, rounded and seen discharging their mucous contents into the interlamellar spaces. The goblet cells are usually transformed from the muciperous basal cells and not from the supporting cells (Fig. 113).

The basal cells:

The basal cells (BC.) occupy lower region of the mucosa and are present in groups underneath the supporting cells, alternating to the nuclei of spindle shaped receptor cells. They are rounded with clearly visible nucleolus and chromatin material. The basal cells are provided with a thin rim of the cytoplasm surrounding the nucleus. These cells are also frequently seen close to the epithelial surface. Some of the basal cells are muciperous and give rise to mucous secretory goblet cells at distal or proximal regions of the lamellae. The frequent mitotic activity showing various stages,

suggesting that they are in process of replacement of other cellular components of olfactory epithelium. The basal cells are observed more activated at the proximal regions of the lamella where they agregate to form protuberances (PROT., Fig. 113). The protuberance is not seen giving rise to new lamellae but increase the sensory surface of the lamella (Figs. 110, 111, 112, 113).

The central core or submucosa:

The mucosa is lined on either sides by a well defined basement membrane containing areolar connective tissue which consists of thick collagen fibres (COL. FI., Fig. 108). The connective tissue supply becomes rigid in the terminal regions of the lamellae forming a turger which provides strength to the lamellae. The areolae are frequently present in the connective tissue. The nonmedullated nerve fibres (NMN. FI.) bundles are observed in the central core of H. dayrixus which receive the fibres of folium olfactorium arising from the axonal ends of the receptor cells of the mucosa. The nonmedullated nerve fibres bundle and blood supply are richly present in the central core. The pigment calls are not observed in the submucosa of the H. dayrixus (Figs. 109, 110, 112, 113).

The raphe:

Unlike C. sarpio, H. fossilis and N. notopterus, the raphe

of H. dentricus is made up of cuboidal and ciliated epithelium which is supplied with spindle shaped receptor cells (SR.) bearing long olfactory cilia (OCI., Fig. 107). The length of the raphe is uniform through out its antero-posterior extension and bear radially projected lamellae on its either sides. The submucosa (SMSA.) is broad and lined on both the sides by a well demarcated basement membrane (BM.) which is in continuation of lamellar outgrowths. This gives a wavy appearance to the submucosa, basement membrane and the cellular epithelial lining of raphe. The submucosa of raphe is filled with dense collagen connective tissue which is supplied with the fibroblast, and basal cells. The bundle of medullated nerve fibres (MMN. FI.) can be seen in the submucosa of raphe. The mucosa is lined by the ciliated cuboidal supporting cells (CI. SC.) which are alternated by the spindle shaped receptor cells (SR.). Due to the supporting sensory nature of raphe, it may probably be assumed as a central lamella giving rise to number of radial outgrowths in H. dentricus (Fig. 107).

DISCUSSION OF ANATOMY

The nasal openings.

The olfactory chambers in fishes are communicated to water by nostrils or nasal openings which are used for transportation of water through the olfactory epithelium and not for breathing unlike the higher vertebrates. In teleosts a pair of nasal openings is present in each olfactory chamber and are named as inlet anterior and outlet posterior nasal openings. Dipnoans, Holocephalids and Elasmobranchs have external nostril which lead to the buccal cavity either in the form of short canal or furrow or deep naso-oral groove. In petromyzon the naso-oral groove is blind and in hag fishes it opens into the buccal cavity (Norman, 1963).

Elasmobranchs have a pair of slit like nasal openings on the ventro-lateral side of the snout. The flap of skin, extending across the middle of each nostril more or less completely dividing it into two parts. The two nostrils are so adjusted that one serves to intake the water and other for its exit (Allison, 1953; Lagler et al., 1962; Malyukina et al., 1969 and Hara, 1975).

In bony fishes, the nostrils are usually situated on the dorsal side of the head, each is divided into incurrent and excurrent passages. A direct connection between nasal sacs and the mouth cavity by means of nasal passage reported for the first time in Dipnoans (Bertmar, 1965) and in some eels of the

family Echelidae and Ophichthidae (ATZ, 1952). The external nostril and internal nostril lie at the opposite end of the nasal passage.

According to Bateson (1889), Burne (1909), Teichmann (1954), Kleerekoper (1969), Norman (1963), Lagler et al. (1962), Hara (1975), the olfactory chamber of most of the bony fishes bears two nasal openings which show considerable variation in their shape, size and location in different fishes. In some fishes, anterior nasal opening is widely separated from the posterior while in others they lie very close to each other. Cichlids (Cichlidae) and certain wrasses (Labridae) have single nasal opening in their olfactory chamber (Norman, 1963).

Among recent fishes, only the scalpins, Cottus (Lagler et al., 1962), Gasterosteus (Pipping, 1926; Lagler et al., 1962), Mugil (Pipping, 1926; Liermann, 1933) Xenentodon (Gupta and Srivastava, 1973; Singh, 1972) possess single nasal opening in their olfactory chamber. According to Burne (1909) the presence of single nasal opening may be the condition created by the elevation of the floor and subsequent rupture of the bridge between the nostrils.

In the present study of C. carpio, E. denricus, H. fossilis, N. notopterus and M. armatus armatus the olfactory chamber of all these five fishes bears an incurrent, anterior and excurrent, posterior nasal openings. The anterior nasal

opening of E. denricus, H. fossilis and M. armatus armatus is in the form of a tube. Burne (1909) reported that the anterior tubular nasal opening is a characteristic of flat fishes, eels siluroids and ophiocephalids. The presence of anterior tubular nasal opening in siluroid, H. fossilis and spiny eel, M. armatus armatus supports the Burne's (1909) statement. However, its presence in Cyprinid, E. denricus contradict the Burne's (1909) finding. Bateson (1889) and Kapoor and Ojha (1973b) advocated that the presence of anterior tubular nasal opening is a characteristic of fishes, with predominently developed olfactory faculty. Kapoor and Ojha (1972a and 1973 b) reported that when anterior and posterior nasal openings are separated from each other by some distance, the former is invariably born on a tube. The statements of Bateson (1889), Burne (1909) and Kapoor and Ojha (1972a and 1973b) seems incomplete as microsmate, E. denricus (in present study), Colisa faciatus and Nandus nandus (Rahmani, 1979) have anterior tubular nasal openings. In E. denricus anterior and posterior nasal openings are very closely situated but former is in a form of well defined tube. However, in N. notopterus anterior and posterior nasal openings are situated at a considerable distance but former is non-tubular. The presence of anterior nasal opening in the form of well defined tube in siluroid, H. fossilis and spiny eel, M. armatus armatus is in accord with the ideas of Bateson (1889), Burne (1909) and Kapoor and Ojha (1972 a and 1973 b) because both these fishes

have well developed olfactory faculty. In A. armatus armatus the distance between anterior and posterior nasal openings is enormous and both are situated at two extremes of the head. The tubular anterior nasal opening is very much elongated in A. armatus armatus, extending beyond the upper jaw where it opens on each side of the fleshy rostrum. In H. fossilis it over hangs on the upperlip and projects in forward direction from the surface of the head. In N. notopterus anterior nasal opening bears a forwardly directed and ventrally grooved nasal tentacle (Sterba, 1962) which helps in deflecting the water to the olfactory chamber through anterior nasal opening. In N. notopterus the anterior nasal opening is situated on an elevated rim like structure.

In C. carpio the anterior nasal opening lies on a distinctly formed lip whose hinder end is continued in the form of a forwardly and outwardly projected hood like nasal flap. This acts as an partition in between anterior and posterior nasal opening and deflects the water to the olfactory chamber through anterior nasal opening. Branson (1963) reported in Hybopsis gelida and H. aestivalis that anterior nasal opening lies on a slight protuberance and partitioned from the posterior by a nasal flap. The nostrils and nasal flap in Cyprinus carpio is in accord with the Burne's (1909) nostrils column IV. According to Burne (1909) and Teichmann (1954) the nasal flap is concave anterior apparently serving to deflect water current downward into the anterior nostril, a rather general arrangement

in bony fishes. But according to present investigation the presence of nasal flap is confined to Cyprinidae and not a general arrangement in other bony fishes.

The nasal flap in C. carpio dips into the olfactory chamber by a curtain like extension from its ventral side and divides the chamber into anterior and posterior compartments. Similar curtain like extension of nasal flap is noted by Branson (1963) in Hybopsis gelida and H. aestivalis, Ojha and Kapoor (1973a) in Labeo rohita. In Garra gotyla (Ojha and Kapoor, 1971) the anterior nasal opening is bounded by distinctly formed lip which projects high above the surface of the snout between two nasal openings but does not project into the olfactory cavity. In Glyptothorax telchitta (Ojha and Kapoor, 1973b) the openings are separated by the backwardly directed nasal flap which serves to prevent the entery of water from posterior nasal opening during the forward progression of the fish.

In C. carpio, B. denricus, H. fossilis, N. notopterus and M. armatus armatus, the posterior nasal openings are considerably larger than the anterior but flush with the general surface of skin of the head in all these five fishes. In H. fossilis and M. armatus armatus the posterior nasal opening is valvular and lies far back than the anterior. In latter species the posterior nasal opening is surrounded by a loose area of integument which performs valvular movement, continuously

throwing the surface in and out. The posterior nasal opening in H. fossilis is crescentic in shape surrounded by wrinkled integumental area at the root of nasal barble. This serves as the excurrent aperture of olfactory chamber as well as the aperture of ventro-lateral accessory sac. It is in agreement with the finding of Burne (1909) "a valved condition (Nostrils, column V) is found chiefly though not solely (some siluroid) in fishes provided with accessory nasal sac, and form part of general mechanism for drawing water forcibly into olfactory chamber through the anterior nasal opening." Ojha and Kapoor (1972) and Kapoor and Ojha (1973) reported valvular posterior nasal opening in Wallago attu and Ompoglossus pleurolepis respectively, but in former species accessory nasal sac is absent. Bateson (1889), Kyle (1899), Burne (1909), Van den Berghe (1929), Liermann (1933), Matthes (1934), Gooding (1963) suggested that posterior nasal opening is usually valvular in the fishes where two openings are situated at a considerable distance. In N. notopterus both the nasal openings lie at a considerable distance but posterior is non-valvular.

In C. garua and E. denricus both the nasal openings are situated very close to each other but posterior is considerably larger than the anterior. Rahmani (1979) in Corax chlorurus, Ojha and Kapoor (1974) in Mystus rhabdophorus and Johnson and Brown (1962) in Sebastodes melanops reported that whenever the two apertures are closely situated, their size discripancy became

minimum. Contrary to this in G. garnia and G. denricus two apertures are situated very close to each other but they show a great discrepancy in their size. In both these species posterior nasal openings are wide, covering most of the part of olfactory chamber and lamellae can be peeped through it. Branson (1963) reported considerable wide posterior nasal opening in Hyboprsis gelida and H. aestivalis. Rahmani (1979) reported poorly developed nasal flap in the posterior nasal opening of Ephinepus orbis but it is rarely found in the form of a tube. The tubular posterior nasal opening is only observed by Kapoor and Ojha (1972a) in Muraena undulata and Burne (1909) in Muraena helena, M. tigrina. Rahmani (1979) is of the view that all these species of genus Muraena are same and wrongly described in the form of different species by Burne (1909).

The author is of the opinion that in most of fishes anterior nasal opening is situated above the surface of head either in the form of a tube or thickened margin of lips or on some protuberans, but posterior is generally flush with surface of the skin. This may be a device for incurrent anterior nasal opening for making easy flow of water through the olfactory chamber from anterior to posterior nasal openings. The placement of the anterior nasal opening above the surface of the head helps in the entry of water current during the foward progression of the fish and similarly the flushed posterior nasal opening allows the exit of same current without any hindrance.

The posterior nasal opening of different fishes show a considerable morphological variation in their shape and sizes. They are either circular (C. carpio) or oval (N. notopterus) or bean shaped (E. denricus) or crescentic (H. fossilis) or rectangular (M. armatus armatus). Burne (1909) and Malyukina et al. (1969) reported that the size and shape of the posterior nasal openings vary significantly in different species. Moreover, Burne (1909) stated that carps, salmons and herrings characteristically possess crescentic posterior nasal pore (aperture). However, Garra gotyla (Ojha and Kapoor, 1971) and Labeo rohita (Ojha and Kapoor, 1973a), Botia botia (Singh, 1972) possess oval posterior nasal opening. All the above species described by Ojha and Kapoor (1971a and 1973a), Singh (1972) are carps with oval posterior nasal opening and therefore the generalization of Burne (1909) cannot stand as characteristic for the carps at least. In the present study C. carpio and E. denricus bear circular and bean shaped posterior nasal openings respectively.

According to Doving and Thommesen (1977) the olfactory passage in fishes is divided into anterior vestibule and posterior gallery. Both these divisions remain connected by a ciliated passage named as corridors which are maintained in between the two lamellae (interlamellar spaces) of a rosette. On the basis of above division Doving et al. (1977) demonstrated that an unidirectional water current is created from vestibule to gallery via corridors. On the basis of the mechanism employed

for the transportation of water through the olfactory chamber, the fishes can be divided in two groups : Isosmates and Cyclosmates Doving et al.,(1977) Doving and Thommeson (1977).

In the former group they placed carps, roach, catfish, eel, rocklings where only ciliary action creates water current through the olfactory chamber while in latter group compression and expansion of accessory sac causes the water to pass through the olfactory chamber. Doving et al. (1977) reported that in cyclosmates fishes the olfactory passage is not divided in vestibule and gallery. In the present study A. armatus armatus and H. fossilis possess anterior and ventro-lateral nasal sacs respectively and can be placed in cyclosmates group. However, both these species are provided with well developed vestibule and gallery. In A. armatus armatus vestibule itself is modified into the anterior accessory nasal sac. In H. fossilis posterior lamellae less part of the olfactory rosette contributes in the formation of well defined gallery.

Contrary to the findings of Doving et al. (1977) C. carpio and B. denricus both carps bear insignificant vestibule and gallery and water is directly entered into the corridors through the anterior nasal opening. In N. notopterus the vestibule and gallery is well developed inspite of the absence of accessory nasal sac. The present author thinks that the division of the olfactory passage is not based on the presence or absence of accessory nasal sacs, but depends upon the morphological structure

of the olfactory chamber and the head. The elongated chamber will be having well defined vestibule and gallery while the short chamber will be devoid of such divisions. The division of olfactory passage is also seen well formed in the fishes where two apertures are situated at a considerable distance.

In the opinion of author the division of olfactory passage, on the basis of accessory sac seems an immature idea of Doving et al. (1977) because H. fossilis and A. armatus armatus (both having accessory sacs) and N. notopterus (without accessory sac) bear well defined division of the olfactory passage viz., vestibule, gallery and corridor.

In C. carpio the nasal flap is dipped into the olfactory cavity, dividing into anterior and posterior compartments. This ventral extension of nasal flap into the olfactory cavity is called as valance (Branson, 1963). The formation of valance is not reported in S. denricus, H. fossilis, N. notopterus and M. armatus armatus. In the latter fish olfactory passage has a continuous central channel (the lumen) which on anterior side communicates the anterior accessory sac and posteriorly opens directly through the opening of the rosette. The corridors open into the lumen.

Rahmani (1979) modified the concept of Doving et al. (1977) by putting a denomination as amphisomates where cilia and action of accessory sac play synchronously in bringing the

water current into the olfactory chamber. In M. armatus armatus the anterior tubular nasal opening is exceptionally elongated which gets modified posteriorly into an anterior accessory sac. This seems an additional device to this mud dwelling fish as mud and other unwanted foreign materials are filtered into the sac and mud free water is allowed into the lumen of the rosette. The internal lining of the sac is composed of hillock accumulation of cuboidal supporting cells with rich supply of mucous secretory goblet cell. The mucous secretion plays an important role in entengling the mud and other foreign materials into the sac. The ciliation is absent in the anterior tubular opening of M. armatus armatus. This is contrary to the findings of Bateson (1889), Kyle (1899), Burne (1909), Van den Berghe (1929), Liemann (1933), Matthes (1934), Gooding (1963) as they reported that ciliated nature of the anterior nasal opening is widely observed in the fishes.

The present author for the first time reported the presence of the opening in the rosette itself in M. armatus armatus which opens ventrally underneath the posterior nasal opening and dorsally to the opening of infranasal chamber.

The olfactory rosette.

The organ of olfaction are represented by a pair of olfactory sacs (chambers) which in sharks and rays are located on the central surface, in sturgeon and bony fishes on the

dorsal surface of the head. The nasal sac (chamber) is lined by the olfactory epithelium which is generally raised from the surface of the organ into complicated series of folds or lamellae to make a rosette (Hara, 1975). The shape of olfactory rosette varies greatly in different species. Bateson (1889) distinguished four types of the rosette : (1) in skate and dog fishes, the lamellae are arranged in a radiating manner, like the septa of orange, (2) the conger and eel, the lamellae are arranged in two rows on each side of the central raphe, (3) the lamellae are fitted together in a radiating manner forming a convex eminance in the olfactory chamber, it is either circular (Cottus, Mottela mustela etc.) or eliptical (mackerel, etc.), such type of rosette is most common in fishes, (4) the lamellae are arranged in single row generally parallel to the long axis of the body of the fish, the raphe is absent, e.g. Solea, Pleuronectus etc.

Burne (1909) reported three types of the olfactory rosette: oval (in most of the fishes); round (in Esox) and elongated (in Anguilla). Fishes with round rosette normally have only a few lamellae and usually show little response to the sense of olfaction. The species with oval rosette are most common but fishes with elongate rosette show dominently developed olfactory faculty. Among 52 genera studied by Burne (1909), the oval rosette is present in 32 genera, elongate in seven and circular and parallel rosette in three each. In few genera

like Belone, Hemiramphus, Exocoetus and Lophius, the rosette is found absent.

Teichmann (1954) tried to explain that the oval (Bateson's, 1889 rosette type 3; Burne's, 1909, rosette column I), circular (Bateson's, 1889, rosette type 3; Burne's 1909, rosette column III) and elongate (Bateson's 1889, rosette type 2; Burne's, 1909, rosette column II) rosette can be linked with his own (Teichmann, 1954) first, second and third groups of eye-nose, eye and nose fishes respectively. In other words Teichmann (1954) identified an oval rosette with equally developed eye and nose faculties, circular rosette with predominently developed optic faculty and elongated rosette with predominently developed olfactory faculty.

In the present investigation it is found that the position of the olfactory chamber in the head and shape of the olfactory rosette vary greatly in all the five fishes selected for the study. The olfactory chamber is close to eye orbit (in C. carpio), close to snout (in H. fossilis), almost in between eye and snout (in A. dayricus) and extending from eye orbit to the snout (in M. armatus armatus and N. notopterus). In M. armatus armatus the olfactory chamber is much elongated due to the elongation of snout and is almost in the form of a barrel which tapers anteriorly and broadens posteriorly. According to Hara (1975) the eels and morays have large olfactory chamber on the dorsal surface of the head extending from the

eye orbit to snout. Ojha and Kapoor (1972a) reported in Wallago attu that olfactory chamber occupies dorsal position of head and lies close to the snout. Kapoor and Ojha (1972 and 1973) reported in Muraena undulata and Channa punctatus that olfactory chambers extend from eye orbit to snout. Branson (1963) in Hybopsis gelida and Hybopsis aestivalis, Ojha and Kapoor (1971 and 1973) in Garra gotyla and Labeo rohita respectively found the olfactory chamber close to the eye orbit than the snout. Hybopsis gelida, H. aestivalis (Branson, 1963), Garra gotyla, Labeo rohita (Ojha and Kapoor, 1971 and 1973), C. carpio and L. denricus (in the present study) possess their olfactory chambers close to the eye and all these species are carps. Therefore, the author is of the opinion that in carps it is generally situated close to the eye but in cat fishes it may be close to the snout as is the case with Wallago attu (Ojha and Kapoor, 1972a) and H. fossilis (in the present study). The position of the olfactory chamber is generally modified with the elongation of jaws as reported in eels and morays (Hara, 1975), Muraena undulata (Kapoor and Ojha, 1972) and subjected to its elongation from eye orbit to the snout, similar is the condition with M. armatus armatus in the present study.

The olfactory rosettes are also subjected to a great modification with the shape and size of the olfactory chamber. It is oval (in C. carpio), rounded (in L. denricus) elongated - leaf shaped (in H. fossilis), boat shaped (in N. notopterus) and

tubular or barrel shaped (in *M. armatus armatus*). Due to the elevated adnasals and nasals in *N. notopterus*, the olfactory chamber becomes considerably elongated and bowl shaped containing boat shaped rosette. Similarly in *M. armatus armatus* elongation of jaws causes the formation of tubular ethmoidal region which is completely filled with barrel shaped rosette.

On the basis of categorization proposed by Bateson (1889), Burne (1909) and Teichmann (1954), the leaf and boat shaped elongated rosettes of *H. fossilis* and *N. notopterus* can be placed under Bateson (1889), rosette type 2; Burne (1909), rosette column II and Teichmann (1954), group III : Oval rosette of *C. carpio* under Bateson (1889), rosette type 3; Burne (1909), rosette column I and Teichmann (1954), group I : rounded rosette of *B. denricus* under Bateson (1889), rosette type 3; Burne (1909), rosette column III and Teichmann (1954), group II. The rosette of *M. armatus armatus* is of a peculiar type and is not correctly reported in literature available. It is a barrel shaped structure made up of ventral and dorsal halves which are fitted on each other by their lateral hinges. The floor of both the halves are thrown into number of lamellae which progress in size antero-posteriorly. A central passage or lumen is maintained in the middle of both halves which posteriorly opens on the ventral side by an independent aperture underneath the posterior nasal opening and anteriorly communicated with the anterior accessory sac. The distal tip of all the lamellae is projected

into the lumen and interlamellar spaces open directly into it. The rosette of M. armatus armatus cannot be placed in any category proposed by Bateson (1889), Burne (1909) and Teichmann (1954).

Kapoor and Ojha (1971b) and Ojha and Kapoor (1973b) reported oval rosettes in Garra gotyla and Glyptothorax lithitia respectively and both have predominantly developed olfactory faculty. Bartmer (1972) suggested that both macrosmatic as well as microsmatic fishes may have oval rosette and thus shape has no concern with the efficiency of the olfactory organ.

In the present study it is found that M. denricus with circular rosette bears predominantly developed optic faculty but C. garua with oval rosette have both faculties equally and predominantly developed. Similar is the condition with N. notopterus where rosette is elongated but olfactory and optic faculties are predominantly developed though the olfactory sensitivity is comparatively higher. H. fossilis and M. armatus armatus show predominantly developed olfactory faculty and optic faculty is very much regressed. The author is of the opinion that oval or elongated rosette shows a great inclination towards the prominent development of the olfactory faculty although optic faculty may also be well developed. Therefore, macrosmatic fishes may be of two types: one having only olfactory faculty prominently developed (for example H. fossilis and

M. armatus armatus) while other with both olfactory and optic faculties well developed (e.g., *C. carpio* and *N. notopterus*). In microsmatic fishes, the olfactory faculty will be regressed but optic faculty will be well developed (e.g., *E. denricus*). The author is of the view that the fishes with both the faculties well developed may act more efficiently in the nature as compared to those having only one faculty (either olfactory or optic) predominantly developed.

In the present study except *M. armatus armatus*, remaining four (*C. carpio*, *E. denricus*, *N. notopterus* and *H. fossilis*) fishes bear an antero-posterior thickening named as raphe. It is leaf shaped in *C. carpio* but in *H. fossilis* and *N. notopterus* is comparatively narrow. In *E. denricus* it is histologically observed that the raphe bears ciliated receptor cells similar to other lamellae. Hence, it can be called as central lamella giving rise to peripheral ones corresponding to the findings of Branson (1963). Cellular composition of the raphe of *H. fossilis*, *C. carpio* and *N. notopterus* reveals total absence of ciliation and receptor cells and is made of simple columnar and basal cells. In *C. carpio* the peripheral zones of the raphe is occupied by the empty theca of goblet cells. Except Ojha and Kapoor (1973) and Branson (1963) no body has discussed it (raphe) histologically. Branson (1963) in *Hybopsis gelida* and *H. zestivalis* recalled it as central lamella containing ciliated and sensory cells but Ojha and Kapoor (1973) in *Labeo rohita*

described it as nonsensory, nonciliated and secretory structure, allowing attachment to the other radial lamellae. The raphe is observed in various fishes as reported by Brune (1909), Sheldon (1912), Tret'yakov (1939) and Teichmann (1954). The presence of raphe is very common in fishes and Burne (1909) observed raphe in forty two fishes out of fifty two studied by him.

It is found that rapheless fishes have comparatively lesser number of lamellae such as Xenentodon cancila 1 (Singh, 1972), Sebastodes melanops 30 lamellae (Johnson and Brown, 1962), sea trout 14-16 lamellae (Bertmar 1972), Channa punctatus 12-24 lamellae (Kapoor and Ojha, 1973a), Anabas testidineus 7-10 lamella (Rahmani and Khan, 1977), Colisa faciatus 5-7 lamellae, and Nandus nandus 7-10 lamellae (both reported by Rahmani, 1979).

Rahmani (1979) reported that generally rapheless fishes are microsmate and other with raphe show better developed olfactory faculty. But contrary to it the raphed H. dayricus is microsmate and rapheless M. armatus armatus possess well developed olfactory faculty. Similarly former species having less number of lamellae while latter with numerous lamellae, contradictory to the idea of raphed fishes with large number of lamellae. C. garua, H. fossilis and N. notopterus are raphed fishes with numerous lamellae arranged on either side of raphe is in accordance with the findings of Branson (1963) and Rahmani (1979).

The number, location, form, and degree of development of folds (lamellae) in olfactory rosette of bony fishes vary significantly (Burne, 1909; Liermann, 1933; and Schmal'hausen, 1962). The largest number of folds (lamellae) has been observed in the olfactory sac (chamber) of Hanlongsarus quentheri (Pfeiffer, 1964). In individual specimen with the length of 480 mm they may number 230 which is significantly larger than all the fishes studied so far. The olfactory chamber of Japanese eel has 90 folds (lamellae) Shibuya, (1960), Anguilla anguilla upto 70 (Teichmann, 1964), burbot more than 50 folds (Teichmann, 1954, 1955) in bream 34-36 (Bodrova, 1962) and in pike and salmon 11-18 folds or lamellae (Teichmann, 1954and Pfeiffer, 1963).

In the present study C. carpio bears 24-36, C. denricus 11-16 lamellae, H. fossilis 46 to 64 lamellae, N. notopterus 58 to 80 lamellae and M. armatus armatus 152 to 240 lamellae corresponding to increase in their total length.

Yamamoto and Ueda (1977, 1978, a,b,c,d,e) reported that the arrangement of lamellae in a rosette is either in two rows on the each side of the raphe or in single row arranged parallel to the body or coming out from a single point. Kapoor and Ojha (1973) in Channa punctatus and Rahmani and Khan (1977) in Anabas testudineus reported the parallel arrangement of lamellae in single row. Burne (1909), Teichmann(1954), Branson (1963), Ojha and Kapoor (1971, 1973a,b, 1974) and Kapoor and Ojha

(1972, 1973) observed that most of the fishes bear two rows of lamellae on each side of the raphe in a rosette.

In the present study the most accepted arrangement of lamellae in two rows on either side of the raphe is seen in C. carpio, B. denricus, H. fossilis and N. notopterus. The arrangement of the lamellae in M. armatus armatus is different from the common plan and contributes to the most peculiar finding of this study. In M. armatus armatus the lamellae are arranged in four rows, two rows in each half of the rosette, in a manner that a well defined lumen (central channel) is maintained in between the both halves. The interlamellar spaces are also maintained which opens directly into the lumen. Such arrangement of the halves and lamellae have not been reported in the fishes studied so far.

The number of lamellae in M. armatus armatus is also highest as mentioned in the available literature. The highest number reported so far is 230 in Haplonecrus guentheri (Pfeiffer, 1964) but in M. armatus armatus is 240 (in the present study). The lamellae in M. armatus armatus originates from the floor of each half and progress in size antero-posteriorly.

The author observed that the lamellae show a clear cut increase in their number with total length of all the fishes of this investigation and this is in agreement with the findings

of Bateson (1889), Burne (1909), Liermann (1933), Teichmann (1954), Eaton (1956), Johnson and Brown (1962), Schmal'hausen (1962), Pfeiffer (1963, 1964), Kleerekoper (1969), Ojha and Kapoor (1971, 1972, 1973a,b, 1974), Kapoor and Ojha (1972a, 1973a,b), Hara (1975) and Doving and Thommeson (1977). However Pfeiffer (1962) reported in Oncorhynchus that the number of transverse lamellae increases with the growth of the fish upto a certain extent and then remains relatively constant. Rahmani and Khan (1977) in Anabas testudineus found that in adult fish the number of lamellae varies from seven to ten and no correlation can be established between the number of lamellae and size of the fish. Davitsyna (1972) is of the opinion that the number of lamellae remains relatively constant and is a characteristic of each species. Consequently, enlargement of the receptor surface is at the expense of an increase in area of the lamellae and not in their number (Devitsyna, 1972).

Burne (1909) reported "considerable differences are apparent in the shape of individual lamenae of the rosette. Starting from the type presented in Gadus as a centre (Rosette, column V.), one line of variation leads by the supersion of the peripheral part of the lamena and the exaggeration of the linguiform process (Rosette, column VI) to a claw-like shape, which is a particular characteristic of the rosette of the salmonidae and clupeidae". In the present study the lamellae

of C. carpio, H. fossilis and N. notopterus bear linguiform process in the middle of distal region of their dorsal surface. The shape of the lamella in C. carpio, H. fossilis and N. notopterus is greatly effected with the presence of the linguiform processes and they are leaf, thumb- and plough-shaped respectively, in aforesaid fishes. The lamellae of H. denricus and M. armatus armatus are devoid of linguiform process. In former it is curved and keeled in latter species.

The linguiform process is also termed as"thumb"by Doving et al., (1977) and it divides the olfactory chamber into central and peripheral channels. In C. carpio, H. fossilis and N. notopterus the linguiform process divides the central cavity of olfactory chamber in to central and peripheral channels but in H. denricus it is undivided due to the absence of linguiform process. In M. armatus armatus central cavity of the rosette is undivided and in the form of continuous channel communicating the vestibule on one side and gallery on the other. In other four fishes (C. carpio, H. denricus, H. fossilis and N. notopterus) the vestibule and gallery are connected by the interlamellar spaces (corridors) but in M. armatus armatus the corridors are communicated with central passage (lumen) directly and not with vestibule and gallery.

Histological findings reveal that olfactory lamellae of C. carpio show a tendancy of bifurcation and trifurcation.

Here crypt formation are also reported which accommodate large number of receptor cells and take a shape of olfactory bud. In H. fossilis minor and curved lamellae are also observed in the present study. In H. fossilis posterior lamellae are seen forming the bud which after detachment from mother attached on the adjacent recipient lamellae, adding a rapid growth to the latter (recipient lamella). The curving of the terminal end of some lamellae has also been observed in H. fossilis. Bertmar (1972), Kapoor and Ojha (1973, 1974) and Rahmani and Khan (1980) reported the extrusion of cells from the terminal end of the lamellae but in present study the lamellae of H. fossilis and C. carnio show a tendency of discharging the "cell ball" from their terminal ends. In N. notopterus a clear cut zonation of sensory and supporting zones has been observed in the lamella. The proximal and middle zone on either sides of the raphe are demarcated as sensory zone while peripheral is supporting, nutritive and vascular in nature. The sensory cellular components are mainly confined to sensory zone. All these observations contribute to the new findings of the present investigations and may significantly be linked with the morphogenetic activity of the olfactory epithelium. Strict zonation in the olfactory epithelium of N. notopterus is a new finding and has not been reported in any fish studied so far. Eaton (1956) reported narrow lamellae in a raphe-bearing fish and he named them "minor fold". Rahmani (1979) observed minor lamellae in Colisa fasciatus.

Ecological co-efficient.

In all animals, except the most primitive, behaviour is largely dependent on a highly organised nervous system. The topography of the brain has been done to study the relative size of the olfactory bulbs and lobes and the optic tectum which reflects the degree of development of olfactory and visual reception. Davis and Miller (1967) also observed that since the development of sensory lobes (or bulbs) reflects hypertrophy of peripheral sensory mechanism, inference about the functional significance of these modilities may be made with reasonable confidence. In the carpsucker, Carpiodes velifer (Miller and Evans, 1965), for example due to great development of taste buds in the mouth and palatal organs, the vagal lobes are large. On the other hand, Evans (1935), Evans (1952), reported that in gadidae, cyprinidae and catostomidae, where external taste buds are numerous, the facial lobes have become enlarged. Thus, the relative development of the different lobes of the brain may reveal to some extent the degree of development of different faculties. Therefore, macrosmatic fishes must have large olfactory lobes and bulbs but have comparatively poorly developed optic lobes, while the microsmatic ones must have just the reverse condition.

The proencephalon is related to olfaction, mesencephalon to vision, and the rhombencephalon to taste, equilibrium and lateral line system (Parker and Haswell, 1951; Legler et al.,

1962). Nevertheless, the brain of teleost has undergone a great modification. The Dipnoans brain is very similar to those of Elasmobranchs, whereas those of Actinoptergii have forebrain architecture shared by no other vertebrates. The brain of Crossoptergii is intermediate (Hildebrand, 1974).

A noteworthy feature in some fishes is the location of the olfactory bulb which lies far away from the brain and is near the olfactory rosette. Such a condition is known as pedunculate. Conversely numerous fishes have sessile type of olfactory bulb i.e., the olfactory bulb is attached with the forebrain.

In the present investigation the olfactory bulb is sessile in M. armatus armatus, pedunculated in H. fossilis, N. notopterus and C. carpio and intermediate in E. denricus. Sessile olfactory bulb has been reported by Marshall (1967) in Ovalothona microdon, Ovena stenu etc. by Hara (1975) in Anguilla, Esox and Salmo and by Schnitzlein (1977) in Anguilla lapponica, Conger myriaster, Muraenesox cinereus. Hara (1975) is of the opinion that most of the teleosts have sessile type of the olfactory bulbs. However, many fishes, for example, selachi (Johnston, 1911, Malyukina et al., 1969), Corydora paliatus (Miller, 1940), Carassius auratus (Schnitzlein, 1964), gadidae (Devitsyna, 1972), Garra gotyla (Ojha and Kapoor, 1971), Wallago attu (Ojha and Kapoor, 1972), Labeo rohita (Ojha and Kapoor, 1973a) and Galeichthyes felis (Morgan, 1975)

have pedunculate olfactory bulbs. Rehmani and Khan (1981), reported sessile type of olfactory bulb in Anabas testudineus, Colisa fasciatus, Nandus nandus, Otolithus argenteus, Ephippus orbis and Caranx oblongus.

A relationship between the sensitivity of olfaction and location of the lobes has not been differentiated (Malyukina et al., 1969). The present findings reveal that no such relationship exists between microsmatic and macrosmatic forms with respect to sessile and pedunculate types. Malyukina et al., (1969)observation is further supported by Marshall's (1967) researches on the bathypelagic fishes. The males of most bathypelagic fishes have large olfactory organs (macrosmatic condition) but females have small or regressed olfactory organs(microsmatic condition), however, both the sexes have sessile bulbs. Thus, the position of the olfactory bulb does not influence the olfactory capacity of the fish. Similarly in the present study H. fossilis and M. armatus armatus have pedunculate and sessile condition of olfactory bulbs respectively but both are macrosmatic fishes.

An intermediate condition between the sessile and pedunculate types have been reported in few fishes. Uchihashi (1953) in Gymnothorax kidako and Coryphaena hippurus, and Doving (1967) in Raniceps raninus found that the olfactory bulbs are located half way between the telencephalon and the olfactory rosette. Such a condition exists in H. dayricus

in the present study.

Though the location of the olfactory lobe has no correlation with the relative development of the olfactory faculty, however, a definite relationship exists between the size of the lobes and the extent of olfactory or visual developments. Microsmatic fishes have small olfactory bulbs, so much so, that it led many workers to believe that they are entirely absent. For example, Mookerjee et al., (1953) reported that in Anabas testudineus and Colisa fasciatus the olfactory bulbs are absent but Rahmani's (1979) findings reveal that the olfactory bulbs are present in both Anabas testudineus and Colisa fasciatus.

The ecological co-efficients calculated by the relative lengths of the telencephalon and mesencephalon and by the areas of the olfactory rosettes and the retinae give distinctive results which can illustrate microsmatic, macrosmatic and eye-nose nature of the fishes under study (Tables 1-5). In H. fossilis and M. armatus armatus the areas of two rosettes and length of telencephalon is considerably higher than the areas of two retinae and length of mesencephalon which discriminate them as macrosmate fishes (Tables 2 and 4). In B. dayricus the area of two retinae is higher than the area of two rosette. Similarly the length of mesencephalon is higher than the telencephalon. This valuation discriminate B. dayricus as microsmate fish (Table 5).

In the cases of C. carpio and N. notopterus though the areas of two rosette is higher but the value of the areas of two retinae can also not be ignored. The significant valuation of both the faculties (olfactory and optic) as well as slightly higher length of mesencephalon than telencephalon indicate eye-nose nature of above mentioned fishes where both the faculties play their significant role in the habit of the fish (Tables 1 and 3).

In the present investigations, area of the olfactory surface and of the eye, and lengths of the telencephalon and mesencephalon are taken as parameters to calculate the ecological coefficients. Both these parameters have intrinsic drawbacks (Rahmani and Khan, 1981).

According to Rahmani and Khan (1981) it is easy to calculate the area of the eye, but the olfactory surface represents difficulties because in some fishes villi like secondary foldings are developed which increase the olfactory area. In Teichmann's method (1954), which is adopted here, no consideration is given to these secondary lamellae. Moreover, it is difficult to calculate the area of these secondary foldings without destroying the lamella. The secondary folds are not uniformly developed so no method could be adopted to calculate the area. Thus in those fishes which have secondary foldings, the areas of the olfactory surface would be higher than calculated by usual methods.

Keeping the above defects in consideration C. garnia is provided with straight projections, hillock elevations, bifurcations, trifurcations, crupts of different shape and sizes whose area cannot be calculated by the usual method. Therefore, the area calculated by the usual methods excludes these microformations, and cannot be considered as accurate measurement. Similar is the case with H. fossilis where calculated area does not have the measurements of minor lamella, and curved lamella. But in both the fishes the area calculated by usual methods gives sufficiently good evidence for discriminating the mentioned fishes as eye-nose and macrosmatic forms respectively. In order to overcome these drawbacks the author also calculated the ecological co-efficient by the length of the lobes of the brain.

Taking into consideration the above drawbacks in each method, the present investigator has compared the two results and then concluded about the habit of the fish. Kapoor and Ojha (1972a, 1973a,b) and Ojha and Kapoor (1971, 1972, 1973 a,b, 1974) have calculated the ecological co-efficient by Teichmann's method (1954) and from their results they have concluded about the habit of fishes. The present studies reveal that there are more chances of error by adopting only Teichmann's method (1954). Therefore, both the brain-lobe method and olfactory area method should be

be adopted and then conclusion should be drawn regarding the fishes understudy.

It is found that C. carpio is an eye-nose fish where both the faculties (eye and nose) play equally efficient role in the habit of the fish. This conclusion is in agreement with the highly active C. carpio which swims near the surface and feeds vorociously by rapidly protruding and retracting the jaws. It easily becomes pet to the master due to its highly sensitive optic and olfactory faculties. C. carpio is an omnivorous feeder and natural food is small animals and parts of the plant .

H. fossilis is a macrosmatic fish exhibiting nocturnal habit and is found in mid holes in dry seasons where it may live for days together. It is not markedly piciverous species and feeds on insects, ostracopods, worms, algal matter, organic debris etc. These characters are in accordance with feably developed optic faculty and significantly olfactory faculty/aid in the livinghood of H. fossilis.

N. notopterus is an eye-nose fish utilizing both the faculties (optic and olfactory) for searching the prey and recognizing the fright reaction. It is a bottom feeder and is found in quite weedy reaches of greater rivers in flood plain and stagnent waters. N. notopterus rests during the day singly or in shool in the shelter of old stems and thick

floating plants. During night they move instantly, close over the bottom, seeking small prey such as insect larvae, worms, small fishes etc., this may probably be due to the highly developed olfactory sensitivity along with sufficiently developed optic faculty.

M. armatus armatus corresponding to its macrosmatic nature, it leads a nocturnal life hiding in day time in mud holes with only the tip of snout protruding out from the borrow. On sun set it comes out in search of small prey chiefly worms, insect-larvae and small crustacean. They thrive best in weedy waters over a muddy or sandy bottoms, where only olfactory faculty plays its important role in the habit of M. armatus armatus.

E. denricus is a microsmatic fish swimming and feeding actively on the surface of water. In accordance to its microsmatic nature it is very much active in day hours, but in night its activity becomes minimised. E. denricus is an omnivorous fish with most varied food such as daphinia, insects larvae, water lice, fresh water shrimps, copepodes and maggots etc. E. denricus inhabits in ponds ditches, reservioirs and rivers.

The author is of the opinion that irrespective of macrosmatic, eye-nose and microsmatic nature of the fishes under study the function of the optic faculty cannot be ignored though its degree of efficiency varies with respect to the above mentioned characteristics. Except for the fishes of

abyssopelagic zone of the sea, dark caves and very turbid waters where vision is minimum or nil, most of the fishes utilize both vision and olfaction for day to day behaviour. In eye-nose fishes and even in nose fishes, vision has an important role to play. The olfactory organ of fishes has a low threshold (Teichmann, 1959; Kleerekoper, 1969; Hara, 1975). The food source or a companion gives off its odour which diffuses and diminished with distance in accordance with something like inverse law of gas diffusion. The concentration of the odour falls off rapidly with distance from the producer. When the receiver receives the odour, it becomes excited and follows the odour gradient. If the receiver is very far off where the gradient has levelled, the excitment and increased activity of the receiver might bring it nearer to the source where the gradient may be useable. Once the receiver is near the source of the odour, its vision now becomes more important. Thus, though a fish may be macrosmat, microsmat or intermediate, both vision and olfaction complement each other and plays an important role in its behaviour.

The circulation of water.

In all the five fishes under investigation, namely, C. carpio, H. fossilis, N. notopterus, E. danricus and M. armatus armatus, it is observed that the water enters into the olfactory chamber through anterior nasal opening, and leaves it via

posterior nasal opening. In other words it can be said that unidirectional flow of water exists in these fishes.

The author thinks that the water always flow from anterior to posterior direction in the olfactory chamber irrespective of architectural differences of the two nasal openings. Doving *et al.*, (1977) reported that the direction of ciliary beat is consistent with the direction of the water currents i.e., the cilia beat from anterior to posterior side of the olfactory chamber. Many workers (e.g., Eaton, 1956; Johnson and Brown, 1962; Kapoor and Ojha, 1973a) have found that the water enters in the chamber through both the openings and is expelled out through the posterior opening (Johnson and Brown, 1962) or through both openings (Kapoor and Ojha, 1973a).

Because the beating of the cilia constantly creates a current of water from anterior to posterior direction then any entry of water through the posterior opening will be an hindrance for the movement of cilia and will also disturb the direction of water flow. Thus unidirectional flow of water from anterior to posterior direction required for efficient working of cilia.

All the five fishes selected for the present study possess cilia in their olfactory epithelium which help the water to circulate in the antero-posterior direction of the olfactory rosette.

In addition to antero-posterior beating of the cilia of olfactory epithelium of all the five fishes, the anterior nasal opening is always situated either on a tube or thickened lip or thickened border but posterior nasal opening is wide and flush with general surface of the head of the fish. This architectural pattern indicates that in forward movement of fish water will compulsorily enter through anterior and exits through posterior nasal opening after irrigating the olfactory epithelium properly. The posterior nasal opening is wide and is considerably larger than anterior, it is valved in H. fossilis and M. armatus armatus but in remaining forms it is without valve. In the case of C. carpio and C. denricus the size of posterior nasal opening is considerably wide, allowing a constant contact of water with the olfactory epithelium in either moving or stationary state. The valved condition of posterior nasal opening of H. fossilis and M. armatus armatus helps in the proper functioning of accessory nasal sac, present in mentioned fishes

In the present study accessory sacs are present in H. fossilis and M. armatus armatus and can be named as ventro-lateral and anterior accessory nasal sacs respectively with regards to their positions in the olfactory chamber. In the former case accessory nasal sac is an extension of the olfactory epithelium to the ventro-lateral side of the olfactory chamber but in latter it is formed due to the modification of anterior tubular nasal opening. Anterior accessory nasal sac in M. armatus

armatus is lined by a secretory cuboidal epithelium where cells are aggregated in the form of hillock elevations. The secretory nature of the anterior accessory nasal sac helps in preventing the mud from the in going water current and allowing mud free water to the lumen of olfactory rosette. This device is in accordance to its mud dwelling habit of H. armatus armatus. The ventro-lateral accessory sac of H. fossilis helps in creating antero-posterior suction pressure synchronously with the unidirectional beating of cilia and thus invites efficient water entry through the olfactory chamber in the antero-posterior direction. The valved condition of posterior nasal opening in H. fossilis allows one way passage of the water current passing through the olfactory epithelium and ventro-valvular movement of posterior nasal opening synchronously with the beating of cilia are responsible for creating the water current through tubular olfactory rosette. Here an additional device for clearing the deposited mud in anterior nasal sac is developed due to the presence of infranasal chamber lying beneath the rosette which acts as the reservior of water. The clearance of olfactory passage takes place due to the creation of reverse water current (after closing the posterior nasal opening) through the anterior nasal opening via anterior accessory nasal sac.

Valves in the posterior pore have been reported in cod and navaga (Devitsyna, 1972), Muraena undulata (Kapoor and Ojha, 1972a), Wallago attu (Ojha and Kapoor, 1972), Glyptothorax

talchitta (Ojha and Kapoor, 1973b). The valved condition of posterior nasal opening is observed in the present investigation in *H. fossilis* and *M. armatus armatus*. The fishes, which do not have valve, possess comparatively small posterior openings for example *Clarias lazera* (Burne, 1909), *Anguilla anguilla* (Teichmann, 1954), *Channa punctatus* (Kapoor and Ojha, 1973a) and *Nandus nandus* (Rahmani, 1979).

When the fish swims in a forward direction a current of water is obviously created from anterior to posterior direction. The anterior nasal tube is always stiff and short thus unbendable and is always directed anteriorly. This architectural adaptation also helps in the entry of water from anterior pore. This statement is justified by the anterior tubular opening of *M. armatus armatus*, *H. fossilis*, *E. denricus* in the present study.

In some fishes, for example, *Garra gotyla* (Ojha and Kapoor, 1971), *Bagarius bagarius* and *Botia dario* (Singh, 1972), *Labeo rohita* (Ojha and Kapoor, 1973a) which do not have any anterior nasal tube, hood like structure is present which deflects the incoming water towards the anterior opening. Burne (1909), Liermann (1933), Teichmann (1954), Johnson and Brown (1962), Gooding (1963), Pfeiffer (1962) etc., have also reported the presence of hood or nasal flap between the anterior and posterior nasal pore. In the present study the nasal flap is present in *G. garra* which helps to deflect water into the

anterior opening during the forward progression of the fish. In *N. notopterus* water current is deflected to the anterior nasal opening by the nasal tentacle (Sterba, 1962), which is forwardly directed and ventrally grouped raised from the thickened border of the anterior nasal opening.

According to Doving *et al.* (1977) when the movement of water across the olfactory chamber is brought about by ciliary action, the fishes are called as isosmates and when it involves the compression and expansion of the accessory sacs, the fishes are placed under cyclosmates categories. In the present study *C. carpio*, *H. denricus*, *N. notopterus* are isosmates, while *H. fossilis* is cyclosmate. *M. armatus armatus* cannot be placed under the category of cyclosmates even in presence of accessory sac because water current is created through the olfactory chamber by continuous valvular movement of posterior nasal opening. Doving and Thommeson (1977) divided the olfactory passage into vestibule, corridors and gallery. In the present study the vestibule in *M. armatus armatus* takes a shape of the lumen of rosette which is enormously elongated opening anteriorly into the anterior nasal sac and posteriorly in the gallery. Corridors open directly into the vestibule. This modification of the olfactory passage of *M. armatus armatus* causes a longest course of circulation of water through the olfactory chamber. In *C. carpio* and *H. denricus* the circulation of water takes a

shortest route due to close location of anterior and posterior nasal openings. In H. fossilis and N. notopterus the route of circulation of water through the olfactory chamber is considerably longer as their nasal openings lie at a distance extending from the snout to the eye orbit. The route of circulation of water through olfactory chamber in A. armatus armatus is longest and has not been reported so far in any fish studied in the available literature.

DISCUSSION OF HISTOLOGY

Histology.

The olfactory epithelium of vertebrate is known to comprise of olfactory receptor cells, intermingled with supporting cells (Hopkins, 1926; Kolmer, 1927; Allison, 1953; Bloom, 1954; Le Gros Clark, 1957; De Lorenzo, 1957; Ottoson, 1963; Porter and Bonneville, 1964; Frisch, 1967; Moulton and Beidler, 1967). Other cellular components are basal cells and mucin secretary goblet cells. The fine structure of the olfactory epithelium has been studied in number of species in fishes by Trujillo-Cenoz (1961), Bannister (1965), Bronshtein and Ivanov (1965), Vinnikov (1966), Wilson and Westerman (1967), Thornhill (1967), Gemne and Doving (1969), Kleerekoper (1969), Schulte and Holl (1971), Bertmar (1972,a), Ojha and Kapoor (1973), Kapoor and Ojha (1974), Hara (1975), Yamamoto and Ueda (1977, 1978 a-f), Zeiske et al. (1979), Theisen et al. (1980) and Rahmani and Khan (1980). It is commonly observed that the basic plan of olfactory epithelium of fish shows no fundamental variation from the general vertebrate pattern. Histologically the lamella of all fishes consists of two principal layers, an outer sensory epithelium or mucosa and a central core or submucosa. The relative thickness of mucosa and submucosa varies from fish to fish and some times even in the lamellae of a rosette. The basement membrane stands as partition in between mucosa and submucosa and serves as medium for the exchange of nervous and neutritional components.

The similar cellular organization of the olfactory epithelium, with individual variation in the arrangement and shape of a particular cell type, has been observed in the study of C. carpio, E. denricus, H. fossilis, N. notopterus and M. armatus armatus. The variation in cellular organization has also been reported among the lamellae of a rosette of H. fossilis.

The supporting cell.

According to Ojha and Kapoor (1973) each supporting cell in Labeo rohita bears 8-12 cilia implanted on basal bodies. In the present study olfactory epithelium of N. notopterus and H. fossilis consists of ciliated and non-ciliated supporting cells arranged in well demarcated zones. In C. carpio ciliated and nonciliated supporting cells are intermingled in the proximal region of each lamella but in distal and middle regions they are exclusively ciliated. In M. armatus armatus and E. denricus all the supporting cells are ciliated. Hopkins (1926), Kolmer (1927), Allison (1953), Branson (1963), Watling and Hilmann (1964), Bannister (1965) and Ojha and Kapoor (1974) reported the presence of only ciliated supporting cells in the olfactory epithelium of fishes. Holl (1965), Bertmar (1972), Rahmani and Khan (1980) described the presence of ciliated and nonciliated supporting cells in the olfactory epithelium of some teleost species. Bertmar (1972,a. ,) reported that there is no difference between the two types of supporting cells in their abundance

or relation to the receptors but when the supporting cells lie together, the group consists of one type of cell. In accordance with Bertmar's (1972,e,) view in N. notopterus and H. fossilis the grouping of ciliated and nonciliated supporting cells reaches upto the extent that the ciliated and nonciliated zones are clearly distinguished. In N. notopterus the ciliated supporting cells are confined in the distal region of the lamella and demarcate a nonsensory, supporting and neutritional zone. The nonciliated supporting cells in N. notopterus are confined to the sensory zone. In H. fossilis the ciliated supporting cells are confined to the proximal region of the lamella on both the sides of the raphe demarcating supporting and sensory zone. The posterior lamellae of H. fossilis are provided with nonciliated cuboidal cells. The nonciliated cuboidal cell of posterior lamellae and non-ciliated columnar cells of distal region of all the lamellae are intermingled with mucous secretary goblet cell in H. fossilis. No secretary goblet cells are observed in N. notopterus among either type of supporting cells. The author is in agreement with Rahmani and Khan (1980) that the grouping of different types of supporting cells may probably have functional significance as reported in N. notopterus and H. fossilis.

In C. carpio the supporting cells are subjected to a process of continuous transformation into the mucous secretary goblet cells, therefore, whole of the peripheral or distal

surface of the lamellae is seen occupied by the theca of goblet cells. The supporting cell in C. carpio can be seen in proximal region of the lamellae but in middle and distal regions they are rarely observed in original form. The transitional stages of supporting cells can very frequently seen in the middle and distal region of the lamellae of C. carpio. Ojha and Kapoor (1973) in Labeo rohita and Kapoor and Ojha (1974) in Channa punctatus observed the supporting cells transforming into the goblet cells. But in C. carpio the transformation of supporting cells in mucous secretary goblet cells, is on mass level and has yet not been noticed in any fish studied so far. In H. fossilis the transitionary stages of supporting cell are also rarely observed in the distal secretary zone of the lamellae. According to Moulton and Beidler (1967) the supporting cells play their significant role in showing their secretary and neutritional activity rather than merely providing mechanical support to the receptors. In the proximal intervening region of the lamellae of C. carpio show that supporting cells may secrete mucous before their transformation into goblet cells. This is in accordance with Kapoor and Ojha (1974) that apart from their supporting function, the supporting cells in the olfactory epithelium have been assigned a role of secretion and isolation of receptor cells. On the other hand Gerebtzoff and Shekapenko (1952) and Gerebtzoff (1953) contradict the idea regarding the secretary nature of supporting cells. Histological observations

reveal that the ciliated supporting cells of C. carpio and nonciliated supporting cells of H. fossilis are supplied with muciperous cytoplasm which may convert in the secretary fluid (mucous) and supporting cell is converted in a goblet cell. In M. armatus armatus mucous secretary goblet cells can be seen in supporting and basal zone in different stages, indicating their transformation from supporting and basal cells. Le Gros Clark and Warwick (1946), Bloom (1954), Yamamoto et al. (1965), Frisch (1967), Seiffert (1968) reported secretary fluid or granules in the supporting cells of different animals. The muciperous activity of supporting cells has recently been reported by Ojha and Kapoor (1973) in Labeo rohita and Kapoor and Ojha (1974) in Channa punctatus. The present author noticed muciperous activity in the supporting cells of C. carpio, H. fossilis and M. armatus armatus. The presence of mucilagenous granules in the fishes has long been reported by Dogiel (1887).

The distribution of supporting cells in E. denricus and M. armatus armatus is uniform and no zonal distinction is seen in the fishes, with respect to their arrangement in the olfactory epithelium. In E. denricus supporting cells are uniformly distributed on the free distal surface of the lamellae and they are alternated by the olfactory vesicles at regular intervals. The supporting cells of E. denricus are uniformly ciliated by small cilia but at distal tips of

the lamellae, ciliation becomes more prominent forming long tuft of cilia which help in creating water current. Internally ciliated supporting cells are followed by primary supporting cells, an advance stage of basal cells leading to the formation of ciliated supporting cells. These supporting cells in *H. denricus* are less tall and confined in the supporting zone of the lamella in a faintly depressed island and project their cilia into the inter-lamellar space. The olfactory cilia are alternated by the cilia of supporting cells but former is more prominent, longer and can be easily distinguished from the latter in *H. denricus*.

Rahmani and Khan (1980) reported in *Anabas testudineus* that sensory cells are grouped in the depressions on free distal surface of the lamellae but in *H. denricus* they form an elevated island at the termination of olfactory vesicle and supporting cells are present in faintly depressed region on both the side of olfactory vesicle.

The supporting cells in *M. armatus armatus* are very closely packed. They are cuboidal in nature allowing the complete isolation of the dendrite of the receptor cells. The supporting cells of the olfactory epithelium of *M. armatus armatus* are intermingled with the frequent distribution of the goblet cells. The supporting cells are arranged in a manner that uniformity of the free distal surface of the

lamellae in M. armatus armatus is maintained. These are uniformly ciliated and proximally followed by the primary supporting cells, an advance stage of basal cells leading to the formation of ciliated supporting cells. In the extreme distal tip of lamella, a marked absence of supporting cells is noticed and place is occupied by the primary neurone which remains in direct contact with the water circulated through the central passage or lumen of the rosette of M. armatus armatus.

In the present study author observed cilia in all the five fishes (C. carpio, E. denricus, H. fossilis, N. notopterus and M. armatus armatus) belonging to different habitat but Gooding (1963) in Katsuwonus pelamis and Gunne and Doving (1969) in Lota lota observed total absence of cilia in the supporting cells. Bannister (1965) has also not described cilia in Phoxinus phoxinus and Gasterosteus but reported that free surface of these cells bear number of irregular microvilli. In the present study microvilli are observed in the nonciliated supporting cells of sensory zone in N. notopterus but nonciliated supporting cells of H. fossilis do not have such formations in their free surfaces.

Holl (1965) suggested the nonciliated supporting cells isolate the receptors and contribute to the metabolism between olfactory epithelium and blood, whereas ciliated types act

for the distribution of mucous on the epithelial surface. Holl (1965) and Pipping (1926) were of the view that ciliary activity of olfactory epithelium creates water current through the olfactory chamber. De Lorenzo (1960) pointed out that supporting cells may be involved in the perception of the sense of olfaction in some way or other. But Kapoor and Ojha (1974) treated this view as an erroneous conception. The author is also of the view that marked and frequent existence of the receptor cells in the olfactory epithelium of fishes under study, leave no chance for supporting cell to perform the function of reception. Therefore, the supporting cells are meant for the maintenance of the integrity of the olfactory epithelium and to provide mechanical support to the dendrite of the receptor cells, keeping them errected in the position for the reception of senses from the water current passing through the olfactory chamber.

The recepter cells.

Rahmani and Khan (1980) reported that recepter cells are almost uniformly scattered in young Anabas testudineus but in adult they are grouped and burried in depression in between the secondary lamellae. Similar condition was observed by Singh (1972) in Bagarius bagarius, Xenentodon cancila and Botia dario and by Iwai and Nakamura (1964) in Thunnus obesus. Malyukina et al.(1962) and Yamamoto and Ueda (1977) also reported that the sensory element are not uniformly distributed

among the other cellular component. In the present investigation author observed that the distribution of receptor cells varies greatly in all the five fishes depending upon the nature of the olfactory epithelium.

In *C. carpio* the receptor cells are irregularly distributed and can be seen in crypts present at different depths of the olfactory epithelium. They are also found in the empty theca of marginal goblet cells, among the ciliated and nonciliated supporting cells and in between the theca of marginal goblet cells in *C. carpio*. In the thicker regions of the olfactory epithelium the receptor cells can be seen at different depths sending their correspondingly elongated dendrites and axons to the free distal and proximal surfaces of the lamellae respectively. In *N. notopterus* and *H. fossilis* they are restricted to proximal and middle region of lamellae leaving their distal regions absolutely non-sensory. In former receptor cells are insoluted and mechanically protected by nonciliated supporting cells while in latter by ciliated supporting cells. The olfactory epithelium of *A. denricus* comprises of deeply embedded receptor cells which send their thick and well marked dendrites to the free distal surface at regular intervals in between the island of ciliated supporting cells. Irregular distribution of the primary neurones have also been seen in the olfactory epithelium of *A. denricus* among the group of basal cells. The

olfactory epithelium of M. armatus armatus is uniform except the tips of the lamellae where it narrows sharply. In the thicker regions of the olfactory epithelium of M. armatus armatus the receptor cells are embedded deep, close to the basal zone and send their enormously elongated dendrites to the distal surface of the olfactory epithelium. The distal tips of lamellae are mainly constituted of primary neurones and remain in constant contact of water passing through the central passage (lumen) of the rosette.

Jogiel (1886), Morril (1898), Jagodowski (1901) and Castello (1956) reported spindle, conical and columnar receptor cell in fishes and frogs. In Salmo, rod and spindle shaped receptor cells are described by Holl (1965). He further reported spindle shaped receptor cells in all teleosts studied by him whereas the rod shaped was only found in Salmo gairdneri, Salmo trutta fario, Esox lucinus, Pleuronectus platessa and Tinca tinca. The olfactory epithelium of C. carpio also represented by three different types of receptor cells ; rounded primary neurones, spindle shaped and rod shaped receptor cells. The rod shaped receptor cells are commonly observed in the olfactory epithelium of C. carpio in between the theca of marginal goblet cells. They end terminally by an expanded tip which bear microvilli. These receptor cells are confined in the supporting zone having considerably thick dendrite and enormously elongated axon. The rod shape receptor

cells some times grouped in between the marginal goblet cells forming "olfactory bud". The spindle shaped receptor cells are also commonly available sensory elements of the olfactory epithelium of *C. carpio* and lie in the middle of mucosa, sending their very much elongated dendrite and axon to distal and proximal regions respectively. The presence of rod shaped receptor cells in the olfactory epithelium of *C. carpio* is in accordance with the findings of Bertmar (1972) who reported these receptor types in sea trout. Kolmer (1927) reported that rod and spindle shaped receptor cells are present in man. Neuhaus (1955) reported four receptor types in dog. Bannister (1965) described variation in the morphology of receptor cells in *Phoxinus phoxinus*. Moll (1965) was of the opinion that the two types (spindle and rod shaped) represent different ontogenetical stages. Bannister (1965) and Moulton and Beidler (1967) described them as the variation of one type resulted due to the tight packing of the cells. The author is of the opinion that rod shaped receptor cells are the characteristics of marine fishes and their presence in the olfactory epithelium of *C. carpio* can be ontogenetically linked as its original home is sea and artificially cultivated in the fresh water pond with the major carps. Their presence also indicate high sensitivity of *C. carpio* with respect to the olfactory behaviour because in higher vertebrates rod shaped receptor cells are common in occurrence.

The formation of crupts in the olfactory epithelium of *C. carpio* is a common feature and this results in the increase of the surface for the reception of olfactory sense and allow abundant accommodation to the receptor cells. In this way the efficiency of *C. carpio* with respect to olfactory sense is tremendously increased. The primary neurones are accommodated in the crupts and project into their (crupts) cavities either by olfactory cilia or protruding end of the dendrites. The crupt may be situated at any depth in the olfactory epithelium and communicated to the interlamellar spaces by broad or narrow openings. The olfactory cilia or protruding end of the dendrite may often project into the interlamellar space. This allows easy contact of the receptor with water circulating through the interlamellar spaces. The deeply embedded crupt gives an appearance of well formed "olfactory bud" in the olfactory epithelium of *C. carpio*. This finding by the present author is a new one because no where such peculiar formations are reported in the fishes studied so far.

The primary neurones, spindle shaped and rod shaped receptor cells in the olfactory epithelium of *C. carpio* maintain their independent identity and no synaptic contact is found in between any two receptor types described herein. This is in agreement with the findings of Ottoson (1963), Yamamoto *et al.* (1965), Moulton and Beidler (1967), Kleerekoper (1969), Graziadei and Metcalf (1971) and Rahmani and Khan (1980).

They described that similar to other vertebrates, fishes are characterised of making direct synaptic contact with the mitral cells of the olfactory bulbs and not in the olfactory epithelium.

Contrary to the findings of above workers Ojha and Kapoor (1973) in Labeo rohita and Kapoor and Ojha (1974) in Channa punctatus reported secondary neurone or spindle shaped receptor cells in the olfactory epithelium which establish synaptic contact with primary neurone before reaching upto the mitral cells of the olfactory bulb. Similar picture of receptor cells have been observed in the present investigation in N. notopterus. In the sensory zone of the olfactory epithelium of N. notopterus serial arrangement of the primary neurones (alternating to nonciliated supporting cells) are seen in supporting zone which are followed by the secondary neurones or spindle shaped receptor cells present in basal zone. The axon of primary neurone establishes synaptic contact with the dendrite of secondary neurone and axon of secondary neurone extends collectively in the form of folium olfactorium along the basement membrane. In addition to the above finding, it is also observed that at certain places secondary neurone or spindle shaped receptor cells does not establish synaptic contact with the primary neurone but sends its filamentous dendrite to free distal surface of the olfactory epithelium. The terminal ending of dendrite in either case forms an olfactory vesicle which bears microvilli.

The author is of the opinion that the establishment of synaptic contact in the olfactory epithelium and presence of primary neurones and spindle shaped receptor cells may be the characteristics of some fishes in which Labeo rohita (Ojha and Kapoor, 1973), Channa punctatus (Kapoor and Ojha, 1974) and N. notopterus (present study) can be listed.

Kapoor and Ojha (1974) described that "the morphological picture available today, the spindle shaped receptor would here seem to apparently correspond to a mitral cell and its axon to a secondary axon fibre which contribute to the formation of the olfactory tract."

The receptor cells of N. fossilis correspond to the secondary neurone of Labeo rohita (Ojha and Kapoor, 1973) and Channa punctatus (Kapoor & Ojha, 1974) but they lie deep in the basal zone as independent unit. They do not form synaptic contact and their dendrite extend upto the free surface of the olfactory epithelium. They can be easily identified by an elongated nuclei and positively eosinophilic dendrite. In the posterior lamellae spindle shaped receptor cells are also observed which are submerged in the supporting zone. The nucleus of latter type of receptor cell is more elongated and possesses equally long axon and dendrite. In the former receptor cells the axon is insignificant in length because of their deeply situated nuclear body but the dendrite of these receptors are exceptionally elongated, thick and project in

the form of olfactory cilia into the interlamellar spaces. The "olfactory bud" formation is absent in the olfactory epithelium of H. fossilis and N. notopterus because each receptor cell is isolated by two or three or more supporting cells.

This indicates that the olfactory epithelium of G. denricus, M. armatus armatus and N. notopterus possesses bimorphic receptor cells while in C. carpio they are polymorphic in nature. This is in agreement with the findings of Jogeil (1887), Jagadowski (1901), Nolmer (1927), Allison (1953), Branson (1963) and Bannister (1965). They described polymorphic type of receptor cells in fish and frog.

The olfactory epithelium of M. armatus armatus is supplied with the spindle shaped receptors lying deep in the mucosa of olfactory epithelium and send their enormously elongated dendrites to the distal or outer surface of the lamella. They form olfactory vesicle in their terminal end which lie deep in the supporting zone of the olfactory epithelium. The primary neurones are concentrated at the distal tip of the lamellae but in thicker region of olfactory epithelium they are irregularly distributed in the basal zone giving rise to their dendrite of varying lengths. The dendrites of the primary neurones of the distal tips of the lamellae are cylindrical and short. Younger neurones can also be seen in the olfactory epithelium of M. armatus armatus whose axon and

dendrites seem in making and they themselves are differentiated from the basal cells. This is in agreement with the findings of Graziadei and Metcalf (1971) who stated that new neurones arise through differentiation of the basal cells and postulate that "new axon should reach the bulb and establish new synaptic contact while old neurones and old contact must necessarily be replaced." The dendrite of varying lengths are reported by Branson (1963), Ojha and Kapoor (1973), Kapoor and Ojha (1974) and Hara (1975).

In the olfactory epithelium of H. denricus the basal cells are seen differentiating in various stages of the primary neurones, dendrites and axon of varying length project out from them. The main and regularly available receptors are spindle shaped cells, lying deep in the basal zone of the olfactory epithelium of H. denricus. They are near to basement membrane and send a thick dendrite to the free surface of the epithelium. The dendrite of these receptor cells is well defined and ends terminally into a broad end which bear long cilia projecting into the interlamellar space. Vinnikov (1955) claimed the cilia of receptor cells as the main element of perception. They act like the antenna of the sensory cell and their movement is directed in search and location of odorants. Similarly the olfactory cilia of the spindle shaped receptor of H. denricus is very much long, motile and project in the form of antenna in interlamellar space. The spindle shaped

receptors in E. denricus are grouped in two or more number and their dendrite terminate collectively in the form of a thick complex of olfactory vesicle on the free surface of olfactory epithelium. This is in agreement with the findings of Graziadei (1971) as he reported that neurones in olfactory epithelium may join together at a specific point through the specialised contact. Similar kind of packing of receptor cells is described by Holl (1965) in catfish Ictalurus and by Bloom (1954) in toads and frogs as pointed out by Bannister (1965) and Moulton and Beidler (1967).

The distal tips of the dendrites of the receptor cells in fish and cyclostomes swells into an olfactory vesicle which bear olfactory hair (cilia) (Jagadowski, 1901; Vinnikov, 1956; Trujillo-Cenoz, 1961; Bronshtein, 1963, 1965; Bannister, 1965; Kleerekoper, 1969; Ojha and Kapoor, 1973; Kapoor and Ojha, 1974 and Rahmani and Khan, 1980). Similar formation of olfactory vesicle is also reported in other vertebrates by Van Der Stricht (1909), Le Gros Clark and Warwick (1946), Bloom (1954), De Lorenzo (1957), Ottoson (1963), Frisch (1967), Moulton and Beidler (1967). The olfactory vesicle formation is observed in the terminal end of the dendrites of receptor cells in N. notopterus, E. denricus and M. armatus armatus. In N. notopterus series of olfactory vesicles are seen in the sensory zone alternating to the nonciliated supporting cells. They are reverse 'V' shaped in structure and bear microvilli

which project into the interlamellar spaces. The accumulation of dendrites of receptor cell on the free surface of the olfactory epithelium of E. denricus take a shape of elevated island (olfactory vesicle) which is alternated to the depressed island of supporting cell. The elevated island is the olfactory vesicle which bears elongated cilia projected into the interlamellar spaces. In M. armatus armatus the olfactory vesicle is present in receptor cells which lies in thicker region of the olfactory epithelium. It is round and vesicular in shape lying embedded in supporting zone and send thick ciliation to the interlamellar spaces. The cylendrical dendrite of primary neurone of the olfactory epithelium of M. armatus armatus bears long cilium on its terminal tip and projects into the interlamellar spaces.

In C. carpio the rod shaped receptor cells are microvillous implanted on their terminal ends but the long dendrite of spindle shaped receptor cell end terminally in the form of simple rounded olfactory vesicle, with elongated cilia. In H. fossilis olfactory vesicle formation has not been observed in the present study and terminal end of dendrites as such project in the form of cilia of different sizes.

Wilson and Westerman (1967) reported cilia and microvilli on the same receptor cells in Carassius auratus similar to the findings of Malyukina et al. (1969). The olfactory receptor cells of C. carpio, E. denricus, H. fossilis, N. notopterus and

M. armatus armatus differ in size, number and structures of the olfactory cilia and vesicle which probably reflect the functional heterogenity of the sensory cells.

Recently Yamamoto and Ueda (1977) identified four types of receptor cells on the basis of the surface specialization, (1) the first type bears 10-30 relatively long cilia on a wide and flat surface. All the cilia of this type inclined in the same direction over the wide range of the epithelium. This is called type one ciliated cell (latter they added that the cilia of type one ciliated cells may be motile and it might be associated with the circulation of fluid between the lamellae) (2) type two ciliated cells has 8 to 12 short cilia which project radially from the round apex of the cell (3) the third type has a tuft of hundred or more microvilli but without cilia and so are called as microvillous cells (4) the fourth is rod cell which neither bears cilia nor microvilli and its apical end protrudes in the form of a simple rod from the epithelial surface. Bannister (1965) and Schulte (1972) also described type 1 ciliated cells but they regarded these cells to be nonsensory. Ichikawa and Ueda (1977) observed it by the retrograde technique that type 2 ciliated cells and microvillous cells are genuine receptor cells, because when olfactory nerve is transected only these two types of cells degenerate, while the type one ciliated cells and rod cells remain uneffected. This proves that type one ciliated cells are not receptor cells.

In the present study it is observed that type one ciliated cells correspond to the ciliated supporting cells of N. notopterus. Here these supporting cells bear more than ten elongated and stout cilia show their inclination towards one side and come out from their wide and flat distal limb. Type 2 ciliated cells correspond to the receptor cells of E. denricus, H. fossilis and M. armatus armatus where cilia are comparatively short and less in number projecting into the interlamellar spaces. The receptor cell of N. notopterus and rod shaped cell of C. carpio are microvillous type (3rd type of cell) but the protruding end of primary neurones in the crupts or empty theca in C. carpio may be identified as type four receptor cells as described by Yamamoto and Ueda (1977).

The mucous secretory Goblet cells.

The mucous secretory goblet cells are important cellular components of the olfactory epithelium of fishes and are found distributed among the supporting cells. The goblet cells are described in the olfactory epithelium of Eliosa brevirostris (Kubiak, 1962), Phoxinus phoxinus (Bannister, 1965), Oncorhynchus (Pfeiffer, 1963), Salmo (Bertmar, 1972 , a), Hagarius hagarius and Botia dario (Singh, 1972), Gadus morrhua, Eleginus navaga and Lota lota (Devitsyna, 1972), Labeo rohita (Ojha and Kapoor, 1973), Channa punctatus (Kapoor and Ojha, 1974). Kleerekoper (1969) described the presence of goblet cells in many species of fishes.

In the present study goblet cells are present in the olfactory epithelium of H. fossilis, M. armatus armatus and C. garnia. The total absence of goblet cells is noticed in olfactory epithelium of N. notopterus but rarely seen in the A. denricus.

The absence of goblet cells are also reported in Xenentodon cancila (Singh, 1972), Hybopsis gelida and H. aestivalis (Branson, 1963), Colisa faciatus (Rahmani, 1979) and Anabas testudineus (Rahmani and Khan, 1980). Holl (1965) described mucous cells in both indifferent and sensory epithelium of Salmo, specially in those places where secondary foldings occurred. Bertmar (1972) also found (in Salmo) that mature goblet cells lie in surface zone, specially of the indifferent epithelium, but also lie scattered in sensory epithelium. Similar to the findings of Holl (1965) and Bertmar (1972) the goblet cells are richly distributed in the olfactory epithelium and are seen at any depth in M. armatus armatus. Here the goblet cells show their migretory tendency and can be seen in formative stages in the basal zone. The grouping of goblet cell has not been observed in the olfactory epithelium of M. armatus armatus, but their presence can be frequently observed in the deeper regions of mucosa. The mucous secretory goblet cells are also observed in the deeper zones of mucosa in Labeo rohita (Ojha and Kapoor, 1973) and Channa punctatus (Kapoor and Ojha, 1974). The goblet cells in M. armatus armatus seem to be originated from the basal cells and discharge their mucous on the free surface

after passing through a migratory cycle from basal zone to the free margins of the lamellae.

In H. denricus the goblet cells are observed in the place where the basal cells show their rapid morphogenetic activity and form bulgings or protuberances from the general surface of lamella. They can be rarely observed in distal end of some lamellae.

In higher vertebrates the olfactory epithelium is kept moist by the secretion of Bowman's gland (Allison, 1953). This gland is absent in the fishes, however, unicellular goblet cells compensate the function of Bowman's gland.

In air breathing vertebrates, the supra-epithelial mucous layer dissolves the particles to be smelled and wash away the material that has already been detected, so that first sample of air can be examined (Hildebrand, 1974). In fishes there is no need for the dissolution of the material to be detected because it is already in liquid form and the constant flow of water washes away the material that has been detected, therefore, the presence of large number of mucous cells in olfactory epithelium in fishes could be explained by the fact that the secreted mucous forms a boundary for the water flow in the olfactory epithelium (Zeiske et al., 1976). The statement of Andres (1966) that in fishes the free surface of receptor cell is directly rinsed by the water flow is not correct (Zeiske et al., 1976). The mucous secretion is overlapped on the

olfactory surface and thus probably helps in smooth flow of water in the olfactory chamber. Rosen and Cornford (1971) reported that the slime has a remarkable capacity to decrease greatly the friction of water in the Pacific Barracuda for example, the friction of water decreases by as much 65.6%.

The olfactory epithelium of *S. sarnia* is abundantly supplied by the mucous secretory goblet cells which are seen at different stages of their formation at variable depths. Among supporting cells they are found to be uniformly arranged in the form of marginal goblet cells. In *H. fossilis* the goblet cells are confined in the indifferent epithelium of distal zone but in some posterior lamellae they are observed in sensory epithelium. Sensory epithelium of middle and anterior lamellae is devoid of the goblet cells in *H. fossilis*.

Bloom and Fawcett (1978) quoted that in mammals the only unicellular glands are the mucous secretory goblet cells which lie scattered among the columnar cells of the epithelium on many mucous membranes. They further pointed out that goblet cells secrete mucous and are made up of an expanded apical end, filled with pale droplet of musin. The basal end is containing compressed nucleus and a small amount of deeply staining cytoplasm. The expanded cup shaped structure is known as theca which remain associated with the basal zone by a thin base like stem.

The structure of goblet cells in the olfactory epithelium of C. carpio, M. armatus armatus and H. fossilis is in accordance with the structure described by Bloom and Fawcett (1978) with reference to mammals. In C. carpio and H. fossilis the theca is expanded cup shaped with clearly visible nuclear complex which takes a shape of compressed structure. In M. armatus armatus the goblet cells are beaked and wine-cup-shaped in appearance. The nuclear contents are compressed but lie within the theca, not in its periphery as is the case with C. carpio and H. fossilis.

Ojha and Kapoor (1973) and Kapoor and Ojha (1974) described varying shapes and sizes of the goblet cells with different phases of their secretory activity. In the present study the shape of the goblet cells in C. carpio, H. fossilis and M. armatus armatus shows great variation. In former two species they are mostly beaked but the latter ones are beakless. The latter goblet cell in M. armatus armatus projects beyond the surface of olfactory epithelium.

The author very clearly observed the migratory tendency of goblet cell in C. carpio and M. armatus armatus. This is due to the fact that they are produced from two sources: first by the transformation of marginal supporting cells and second by the muciperous basal cells. In the latter case the basal cell along with its transformation into the goblet cell undergoes to cyclic movement from basal to the supporting zone. This brought the

goblet cell, originated from basal cell, to the free surface where mucous is discharged.

In C. carnio the proximal intervening region of the lamella is pooled with muciperous basal cells which undergoes a process of transformation into the goblet cells. Whole of the olfactory epithelium of C. carnio can be seen with different sizes of goblet cells, in the way of their migration from basal to supporting zone. The tremendous tendency of production of goblet cells from muciperous basal cells for the first time observed by the present author in C. carnio. In A. armatus armatus the muciperous basal cells are present and transform into the goblet cell, but is not at the rate of C. carnio. The migratory tendency can easily be demonstrated in M. armatus armatus and C. carnio.

In C. carnio marginal goblet cells are resulted due to the continuous transformation of supporting cells in these (goblet cells) cell types, therefore, whole of the marginal surface of lamellae is seen occupied by the theca of goblet cell except few original or transitionary supporting cells. This is in agreement with the findings of Mee (1985) who described the goblet cell as the modified columnar supporting cells. The transitionary stages of columnar supporting cells can easily be seen in the olfactory epithelium of C. carnio, H. fossilis and M. armatus armatus.

In H. fossilis muciperous basal cells are not seen and

goblet cells are produced by the nonciliated supporting cells of nonsensory region. They are also produced by the cuboidal supporting cells of posterior lamellae in H. fossilis.

Present author attempts to classify the goblet cells in two categories (1) stationary goblet cells produced by the marginal supporting cells (2) migratory goblet cells produced by the mucliperous basal cells which undergo a course of migration from basal to supporting zone. In the former category, the theca is ovoid cup shaped and opens directly from the free surface of the olfactory epithelium, can be named as "Mega goblet cells" while latter with rounded and comperatively smaller theca, may termed as "micro goblet cells".

C. garnia shows a tremendous capacity of transforming basal cells into the goblet cells which may be grouped and fused at variable depths in the olfactory epithelium. Due to the grouping and fusion of migratory goblet cells in large number, causes the formation of complex structure which may burst from the general surface of the olfactory epithelium. This results in the formation of erupts of variable shapes where large number of receptor cells can be accommodated. In this way the area of sensory surface in the olfactory epithelium of C. garnia is greatly increased. The erupts along with the sensory elements appear like a well formed "olfactory bud" which found embedded at different depths in the olfactory epithelium.

The migration of goblet cells and their subsequent increase in the size of theca in the middle of olfactory epithelium, cause the displacement of basal cells which are forced to flow in any direction resulting the microformation such as hillock elevation, straight projection, bifurcation and trifurcation. The enlarged theca of marginal goblet cells and its grouping with other migratory goblet cells cause the interruption of the olfactory epithelium in C. carpio.

The basal cells are subjected to a pressure of enlarged theca which forced for their rapid morphogenesis and flow to any direction leading to the number of microformations on the general surface of the lamellae in C. carpio.

The grouping of goblet cells, formation of crypts and differentiation of goblet cells in mega and micro- forms contribute to the unique finding of the present research work. Bertmar (1972) denied the possibility of grouping of goblet cells in the olfactory epithelium of fishes.

Bloom and Fawcett (1978) quoted that the secretion of mucous proceed more or less continuously and all retain its most of the life span which is only two to four days in the intestinal mucosa. Although goblet cell normally passes through only one long secretory cycle but they may be made to expel nearby all of their secretion at once.

Similar secretory nature of the goblet cells is found in

C. carpio, *H. fossilis* and *M. armatus armatus*. After discharging the mucous the goblet cells are supposed to dead and theca forms empty space where flow of basal cells may be possible. But some time number of empty goblet cells meet at a point and allow the detachment of the part of lamella or cell ball in *H. fossilis*. The distal ends of lamellae are seen continuously discharging the cell balls which may be due to the meeting of empty theca of goblet cells and subsequent narrowing of underneath region of detached portion. The detachment of terminal ends of the lamellae is also noticed in *C. carpio*.

In the process of budding in *H. fossilis* the theca of goblet cells, after discharging the mucous provide a way for the flow of basal cells which aggregate at distal end of the mother lamella in the form of a bud. The further activity of goblet cell at the junction of bud and mother lamella causes its (bud) detachment. The attachment of bud on the recipient lamella is based on the morphogenetic activity of basal cells with the enlargement of goblet cells and their flow in the way formed by the empty theca. The basal cells cause the elongation of bud and empty theca of goblet cells create a place for the meeting of bud and recipient lamella which allow the fusion of each other. The cell balls and bud are mainly constituted of basal cells and goblet cells.

The association of the goblet cell with aquatic mode of life can be traced out because they are present in the fishes

(Whitaker, 1970), amphibians (Farquhar and Palade, 1965) and aquatic snakes (Banerjee and Mittal, 1978). Their presence in aquatic form is to minimise the friction between the body and water and thus increases the mobility of the animal. The mucous secretion also allows the smooth flow of water into the olfactory chamber and protects the sensory epithelium with direct effect of water friction in fishes.

Vinnikov (1965) thinks that mucous layer contributes in the active reception of olfactory senses. This could probably be justified due to their presence in macrosmatic forms such as Labeo rohita (Ojha and Kapoor, 1973), Channa punctatus (Kapoor and Ojha, 1974), C. garnia, H. fossilis and M. armatus armatus (in the present study) which show high sensivity of olfactory behaviour.

The present author 's of the opinion that goblet cells are certainly related with the increase in the surface of olfactory sensation and help in removing the debris from the olfactory surface by entengling them in mucous secretion. They are ultimately removed out side by the forcibly passing of water current in any direction.

Devitsyna (1972) studied two marine species Gadus morhua, Hlacimus norvegs and fresh water Lota lota. He concluded that goblet cells can be assumed in some way to promote the olfactorily active substances in the salt water. The author is of the opinion that goblet cells can not be the only distinctive feature

of marine fishes, as they are observed in fresh water forms. The presence of goblet cell in the olfactory epithelium of H. fossilis, M. armatus armatus and C. carpio therefore contradicts the idea of Devitsyna (1972).

The basal cells.

In all the vertebrates including fishes, the basal cells occupy proximal position just above the basement membrane (Allison, 1953; Graziadei, 1965; Andres, 1966; Wilson and Westerman, 1967; Gemne and Døving, 1969; Singh, 1972; Bertmar, 1972; Ojha and Kapoor, 1973; Kapoor and Ojha, 1974; Hara, 1975; Zeiske et al., 1976; Bronshtein, 1976; Yamamoto and Ueda, 1977; Rahmani and Khan, 1980). These cells are undifferentiated and give rise to supporting cells (Schaeffer, 1932; Cordier, 1964; Ojha and Kapoor, 1973) or to the receptor cells (Andres, 1966; Thornhill, 1970; Graziadei and Metcalf, 1971) or both types of cells (Bertmar, 1972; Hara, 1975).

In the present study of C. carpio, B. denricus, N. notopterus, H. fossilis and M. armatus armatus, the basal cells occupy lower region forming clear cut basal zone just above the basement membrane. In N. notopterus the basal cells show a scanty supply in the supporting zone but in sensory zone they seem completely transformed in the sensory components. In the supporting zone of N. notopterus the basal cells are present in a uniform single row below the proximal limbs of the supporting

cells. Their accumulation is also seen in the supporting zone which gives an impression of their possible transformation into the supporting cells. This is in agreement with the statement of Kolmer (1927), Schaeffer (1932) and Cordier (1964), According to these workers they (basal cells) are additional or younger forms of supporting cells which may ultimately replace the latter in olfactory epithelium. The scanty supply of basal cells in the olfactory epithelium of N. notopterus in the supporting zone speaks that they have already transformed into the supporting cells and remaining are the reserve cellular component for the replacement of old and worn out supporting cells in N. notopterus. This contradicts the opinion of Shantha and Nakajima (1970) who contended that basal cells could not possibly give rise to the supporting cells. In E. denricus the basal cells are present in groups alternate to the spindle shaped receptor cells and below the supporting cells. In the groups of basal cells some are identified as the primary neurones bearing dendrite of varying length and short axon extending upto basement membrane.

Thornhill (1970), Graziadei and Metcalf (1971) by using tritiated thymidine followed by autoradiography, have recently attempted to show that basal cells of the olfactory epithelium also differentiated into the olfactory neurones which are continuously replaced during the life time.

The basal cells in C. carpio are abundantly present and

show their frequent accumulation in the basal zone which lead to the replacement of damaged and worn out cellular component of the olfactory epithelium. The basal cell shows a tendency of their flow in any direction leading to the microformations. In such region they accumulate in large numbers and undergo a process of transformation of other cellular component of olfactory epithelium. They act as cellular reservoirs and are greatly effected by the migratory goblet cells whose theca occupy larger area of olfactory epithelium. This causes displacement of the basal cells, leading to their flow in any direction of the formation of hillock elevation, straight projections, bifurcation and trifurcation on the general surface of the olfactory epithelium of C. carnio. The basal cells can also be observed in the supporting zone justifying their transformation into the supporting cells.

Present author for the first time identified the mucuperous basal cells in olfactory epithelium of C. carnio and M. armatus armatus. Such basal cells are richly accumulated in the proximal intervening regions on the either sides of raphe and show rich granulation but in M. armatus armatus they can be seen in the basal zone any where in the olfactory epithelium of the lamellae. The mucuperous basal cells undergo a cyclic migration from basal to supporting zone in the preparation of the formation of complete goblet cells which discharge their mucous secretion at the free distal surface of olfactory

epithelium in C. carpio and M. armatus armatus. In the former species positively muceperous basal cells may group at any depth of the olfactory epithelium and form complex structure of crupts which may be of variable shape and size opening through the free surface of the lamella by broad or narrow opening. The population of basal cell in M. armatus armatus is comparatively rich and packed compactly. Their differentiation into primary supporting cells can be seen in M. armatus armatus, H. denricus and C. carpio.

In H. fossilis they are distributed in two zones: first in sensory zone and supporting zone and second in indifferent epithelium of distal zone. In former they are scantly present in a single row but in latter they form a thick and multilayered basal zone. They are also present in many layers in posterior lamellae below the cuboidal supporting cells. The basal cells show their flow into the terminally detached cell balls in middle lamellae and in posterior lamellae they flow to form bud. The bud and detached cell balls are richly supplied with the basal cells which may transform these fragments into the complete lamella or provide nutritional supply to the other part of the olfactory epithelium.

The basal cells are observed in the accessory secs of H. fossilis and M. armatus armatus which give rise to the formation of hillock elevations in the internal lining of the

sac. The goblet cells and cuboidal supporting cells are also continuously replaced by the basal cells. The raphe of all four fishes (C. carpio, E. denricus, H. fossilis, N. notopterus) bear a clear basal zone which may be constituted of one or more layers of basal cells.

Rahmani and Khan (1980) reported that frequent mitosis is reported in the basal cells suggesting that they are in preparation for the formation of other cell types. The basal cells are observed in the connective tissue of central core or submucosa of raphe in C. carpio, E. denricus, H. fossilis and N. notopterus. The submucosa or central core of above fishes and M. armatus armatus bear variable supply of basal cells, fibroblasts, lymphoids and histocytes which are found impregnated among the connective tissue fibres.

The pigment cells.

The epithelium pertaining to senses of hearing, olfaction, taste and touch is peculiarly supplied with pigment cells. The function of pigment cells is not fully known but it seems that they might be enhencing the smelling and hearing powers in the animal in some way or other (Allison, 1953). It is significant that albino animals in which the pigment cells are lacking, are particularly liable to poisoning (Allison, 1953). Malyukina et al. (1969) think that there exists a relationship between the intensity of colours of olfactory epithelium and the sensitivity

of the organ of smell: darker the epithelium the higher the sensitivity. Hildebrand (1974) also favours the view that pigment may enhance olfaction in some unknown way.

In the present study the olfactory rosette is coated by a thick sheath of pigment cells which are found impregnated in the connective tissue fibres of A. armatus armatus. Blood vessels and nerves running along the barrel shaped rosette are also encircled by the pigment sheath. The submucosa of raphe and lamella is supplied with the pigment cells in C. carpio, H. fossilis and N. notopterus. They are branched and entangled in the fibres of connective tissue. In N. notopterus they are more prominent and rich in supporting zone of lamellae and raphe and are usually confined near the blood capillaries. The pigment cells are not observed in the submucosa of raphe and lamellae of E. denricus.

Devitsyna (1972) on the basis of comparative study of three gadoid fishes concluded that pigmentation of olfactory plates is a characteristic feature of some species with a reduced olfactory function. Merlangus pleginus bears pigment cells while the lamellae of Lota lota and Gadus morhua are devoid of these cells.

The present author observed pigment cells in all macrosmatic species (C. carpio, H. fossilis, N. notopterus and M. armatus armatus) but are absent in microsmatic form (E.denricus).

Therefore, it can be concluded that presence of pigment cells is related with the increase in olfactory behaviour and is not with the reduction of olfactory function. The author contradicts the findings of Jevitsyna (1972) and believes that the occurrance of pigment cells is the characteristics of a highly sensitive sensory organ.

SUMMARY

SUMMARY

The anatomy and histology of olfactory organ of five freshwater teleost fishes (C. carpio, H. fossilis, N. notopterus, M. armatus armatus and E. denricus) have been described. The olfactory chamber in all five fishes lies on the dorso-lateral surface of the head. It is situated close to eye orbit in C. carpio, close to snout in H. fossilis, in between eye orbit and snout in E. denricus, extending from eye orbit to snount in N. notopterus and M. armatus armatus. In the latter species olfactory chamber is enormously elongated and barrel shaped.

The olfactory chamber in all the fishes under investigation communicated out side by an incurrent, anterior and an excurrent, posterior nasal openings. The nasal opening in C. carpio and E. denricus lies very close to each other but in N. notopterus and H. fossilis at a considerable distance. The anterior and posterior nasal openings in M. armatus armatus are situated at the two extremities of the elongated snout.

The anterior nasal opening in H. fossilis, E. denricus and M. armatus armatus is in the form of a tube which is anteriorly and forwardly directed. In M. armatus armatus anterior nasal tube is considerably elongated which opens on the either side of fleshy rostral appendage forming a trilobed structure at the termination of upper jaw.

The anterior nasal opening in C. carpio and N. notopterus is nontubular but born on a thickened rim which in former species bears a nasal flap but in latter provided with a nasal tentacle. The nasal flap and tentacle help in deflecting the water to the anterior nasal opening in C. carpio and N. notopterus respectively.

The posterior nasal opening in all the five fishes flush with the general surface of the skin and is valved in H. fossilis and A. armatus armatus. It is nonvalvular in N. notopterus, C. carpio and C. denricus. In latter two species, it is considerably wide and allows a constant contact of the olfactory epithelium with water. The posterior nasal opening in H. fossilis and A. armatus armatus is made up of two lips which in former are known as anterior and posterior lips while in latter as ventral and dorsal lip. The former lip extends over the latter in both the species giving a shape of a valve. The integumental surface of posterior nasal opening is continuously making valvular movements which help in creating the water current through the olfactory chamber.

The olfactory rosette shows a great variation in shape, size and number of lamellae in all the five fishes. On the basis of categorization proposed by Bateson (1889), Burne (1909) and Teichmann (1954), the leaf or boat shaped rosette of H. fossilis and N. notopterus can be placed under Bateson (1889) rosette type 2; Burne (1909) rosette column II

(1954) rosette group III; oval rosette of C. carpio under Bateson (1889) rosette type 3; Burne (1909) rosette column I and Teichmann (1954) rosette group I; rounded rosette of E. denricus under Bateson (1889) rosette type 3; Burne (1909) rosette column III and Teichmann (1954) group 2. The enormously elongated barrel shaped rosette of A. armatus armatus has not yet been reported correctly and, therefore, cannot be placed in any of the categorization mentioned above.

The olfactory rosette in C. carpio, H. fossilis, E. denricus and N. notopterus bears an antero-posteriorly elongated raphe, dividing it in two equal halves. The lamellae are attached on both the sides of raphe in all these four species. In A. armatus armatus rosette is raphe-less and is made up of two dorsal and ventral halves, fitted on each other by their lateral hinges. Here four rows of lamellae (two in each half) are present which arise from the floor of each half.

The number of lamellae varies from 24-36 in C. carpio, 11-16 in E. denricus, 46-64 in H. fossilis, 58-80 in N. notopterus and 152-240 in A. armatus armatus. The number of lamellae is highest in A. armatus armatus against the highest number 230 reported in Haplopsarcus quentheri (Pfeiffer, 1964). The lamellae of C. carpio, H. fossilis and N. notopterus bear linguiform process in their dorsal surface but in the lamellae of A. armatus armatus and E. denricus it is absent.

As regards the relationship of the brain with the olfactory rosette it is found that olfactory bulb is sessile in A. armatus armatus, pedunculate in C. carpio, H. fossilis and N. notopterus but it is intermediate in A. denricus (intermediate condition is rarely reported in the fishes).

The ecological co-efficient is calculated by the areas of two retinae, two rosettes and by the length of telencephalon and mesencephalon. It is seen that C. carpio and N. notopterus are eye-nose fishes where both the faculties are well developed. A. armatus armatus and H. fossilis are macrosmatic forms where only olfactory faculty is well developed. A. denricus stood microsmatic type of fish where optic faculty is well developed. An attempt has also been made to correlate the eye-nose, macrosmatic and microsmatic characteristics of these fishes with their general habits. Macrosmatic A. armatus armatus and H. fossilis lead a nocturnal life inhabiting in dark places and mud holes. Microsmatic A. denricus leads an active life in day hours, swimming and feeding actively on the surface of water. N. notopterus and C. carpio being "eye-nose" fishes lead active life both in the day and night hours.

The flow of water through the olfactory chamber is unidirectional in all the five fishes which is created by the antero-posterior beating of cilia. In H. fossilis the creation of water current through olfactory chamber is assisted by the compression and expansion of ventro-lateral accessory sac but

in *M. armatus armatus* continuous valvular movement of posterior nasal opening assists in bringing the water current through the olfactory chamber.

The olfactory passage of *M. armatus armatus* is longest whereas in *C. carpio* and *E. denricus* it is shortest. In *H. fossilis* and *N. notopterus* the passage is of moderate size. The vestibule and gallery is well demarcated in *H. fossilis* and *N. notopterus* but in *M. armatus armatus* vestibule takes a shape of lumen. In *H. fossilis* posterior lamellaeless area contribute in the formation of well defined gallery. Corridors are the interlamellar spaces which inter connect the vestibule with gallery. In *M. armatus armatus* anterior accessory sac is present, which entangled mud and other foreign particles and mud free water is allowed in the lumen of the rosette.

Histological observations reveal that each lamella in all the five species (*C. carpio*, *H. fossilis*, *N. notopterus*, *M. armatus armatus* and *E. denricus*) is made up of a central core of submucosa, lined on either sides by the cellular layers of mucosa. The basement membrane stands as partition inbetween the mucosa and submucosa. The mucosa in *C. carpio*, *H. fossilis*, *M. armatus armatus* and *E. denricus* is mainly constituted of supporting cells, receptor cells, mucous secretory goblet cells and basal cells. *N. notopterus* possesses all the above mentioned cellular composition except mucous secretory goblet cells.

The olfactory epithelium of lamella in all the five fishes, shows a great variation in the composition of olfactory epithelium and number of microformations are observed in the present investigation.

The olfactory epithelium of the lamellae of C. carpio is provided with number of microformations such as hillock elevations, straight projections, bifurcations, trifurcations and crupts of variable shape and sizes, lying embedded at different depths in the olfactory mucosa. The crupts accommodate large number of primary nurones and open through the surface of lamella by narrow or broad opening, forming well defined "olfactory bud" where olfactory cilia and protruding ends of dendrites receive the sensation from the water current passing through the interlamellar spaces. All the microformation and crupts lead to increase the area of olfactory surface in C. carpio.

A tremendous tendency of the transformation of supporting cells in the mucous secretory goblet cells is noticed in the C. carpio, therefore, whole of the peripheral surface of the lamella is seen occupied by the theca of goblet cells.

The migration, grouping, fusion and subsequent rupture of large number of the goblet cells are seen scattered in the olfactory epithelium of C. carpio. This activity of goblet cells causes the displacement of basal cells which may flow to any direction leading to microformation. The rupture of the goblet

cells in groups causes the interruption of the olfactory epithelium in the form of crupts. The grouping of the dendrites of rod shaped receptor cells on the general surface of olfactory epithelium also form "olfactory bud" in C. garnia.

On the basis of cellular composition, the lamellae of a rosette in H. fossilis can be divided in initial, middle and hinder groups. The initial and middle lamella show a zonal differentiation inbetween the proximal and distal regions. The former is composed of columnar ciliated supporting cells with rich distribution of spindle shaped receptor cells while latter is lined by the goblet cells intermingled with non-ciliated supporting cells. The hinder lamellae do not show any zonal demarcation and are uniformly lined by the nonciliated cuboidal supporting cells where submucosa is enormously developed. The beaked micro-goblet cells and spindle shaped receptor cells are distributed among the cuboidal supporting cells irrespective of any zonal distinction.

The minor and curved lamellae are seen in the olfactory epithelium of H. fossilis. The bud formation is noticed in the hinder lamellae which after detachment from mother attached on adjacent recipient lamella and adds immediate growth to the latter.

The terminal parts of some lamellae in H. fossilis are seen discharging "cell balls" by the process of gradual

constriction of the underlying region. At the places of curving and attachment with bud, the terminal ends of lamella show an abnormal swelling in the submucosa which may be due to the accumulation of basal cells, blood capillaries and connective tissue etc. required for the fulfilment of these processes (attachment and curving).

In N. notopterus the clear cut zonation of sensory and supporting zones can be observed in all the lamellae in an uniform pattern. The proximal region on either sides of the raphe in each lamella is demarcated as nonciliated, microvillous and sensory zone while remaining distal region is known as ciliated supporting zone. The synaptic contact inbetween the axon of primary nurones and dendrites of spindle shaped receptor cells can be frequently seen in the sensory zone of N. notopterus.

The olfactory epithelium of A. denricus and A. armatus armatus is almost uniform except in latter species where terminal tips of the lamellae are solely occupied by the primary nurones. In A. denricus faint elevations and depression are observed in the general surface of the lamella which are alternately supplied with longer (olfactory cilia) and smaller cilia. In the proximal region of few lamella, morphogenetic activity of cells can be observed which give rise to protuberance like structure bearing goblet cells and aggregation of basal cells in A. denricus.

The olfactory epithelium of *M. armatus armatus* and *E. denricus* is supplied with primary nurones and spindle shaped receptor cells. *H. fossilis* bears only one type of receptor cells which correspond to the spindle shaped receptor cells lying deep in the olfactory epithelium. *C. carpio* possesses primary nurones, spindle shaped and rod shaped receptor cells at variable depths in the olfactory epithelium. *N. notopterus* is provided with spindle shaped receptor cells and primary nurones which make synaptic contact inbetween them. The olfactory vesicle of variable shape and sizes is seen at the terminal end of the dendrites of the receptor cells of *C. carpio*, *E. denricus*, *M. armatus armatus* and *N. notopterus* but in *H. fossilis* dendrite projects into the interlamellar space by a simple olfactory cilia. The olfactory vesicle in *C. carpio*, *E. denricus*, *M. armatus armatus* and *N. notopterus* bears either olfactory cilia or microvilli or both.

The migratory tendency of the goblet cells can be demonstrated in the olfactory epithelium of *C. carpio* and *M. armatus armatus* where goblet cells are produced by mucipe-rous basal cells and undergo a cyclic movement from basal zone to supporting zone where mucous is discharged.

The aggregation of basal cells is reported in the olfactory epithelium of *C. carpio*, *N. notopterus*, *E. denricus*, and *M. armatus armatus* at variable depths of mucosa, giving an

impression of their possible transformation in other cellular constituents of the olfactory epithelium in the process of the repair or replacement of the damaged or worn out parts of the mucosa. In H. fossilis aggregation of basal cell is reported in "cell ball" and "bud" which may probably be supplied to other needy parts of the olfactory epithelium.

The branched pigment cells are observed in the submucosa of H. notopterus, C. carpio, H. fossilis, which are found submerged in the connective tissue fibre. The pigmentation in A. armatus armatus is in the form of thick pigment sheath encircling the whole rosette and giving it a dark black appearance.

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